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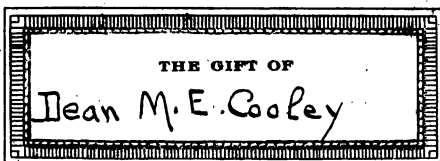
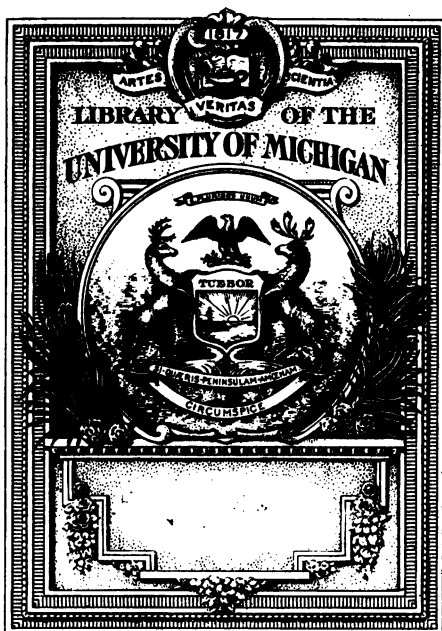
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HARPER'S

# HYDRAULIC TABLES

## FOR THE FLOW OF WATER

IN CIRCULAR PIPES UNDER PRESSURE,  
TIMBER FLUMES, OPEN CHANNELS,  
AND EGG-SHAPED CONDUITS

*WITH MUCH ACCESSORY INFORMATION*

BY

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## PREFACE

THE reader will not find within the limits of this work a critical treatise upon hydraulics. In discussing, within the space that is here assigned, formulas that cover a large field, all theoretical refinements and many practical details must be passed without notice.

Nor are the tables designed for the precise determination of every problem that may arise; but they are intended to secure by direct inspection, or with easy mental interpolations, a close approximation to the answer desired. The results, thus obtained, will often be exact enough for any purpose, and if the functions are reasonably well balanced and all conditions remain within practical limits, they will be found accurate enough for the solution of any problem that is likely to arise in an ordinary engineering practice.

My purpose has been to cover the hydraulic field with a network or grill of solved problems, wherein one may find something that will lie tolerably near any question that may arise, regarding the flow of water in either closed or open conduits, with any reasonable assumption of rugosity and with any rational arrangement of grade, in quantities from a small fraction of a foot to several thousand feet per second.

I would have regarded the work as quite beyond my efforts had it not been for the elaborate tables compiled by Mr. P. J. Flynn, C.E., for his "Flow of Water in Irrigation Canals," published by George Spaulding & Co., of San Francisco, Cal., in the year 1892. When available, I have used Mr. Flynn's tabulated coefficients without reserve, and have followed his methods in computing others as required.

The number of exact determinations by this handbook is small when compared with those made possible by using Mr. Flynn's tables, but I have carried the work a step further than he, and give a series of solved problems from which the approximate information is obtained by direct inspection. In

addition to the standard velocity and discharge tables, a number supplemental thereto have been prepared, some of which will simplify interpolations and comparisons when using the main tables, while others will at times be found convenient for reference and a ready assistant in making computations.

The controlling motive of the author has been to present in pocket form, at least one practical solution that will closely approximate any reasonable problem that may arise regarding the flow of water, together with such accessory information as the limits thus prescribed would permit.

Should the profession find these tables as convenient as the compiler thinks he would have found such a volume in his own practice, he will consider himself abundantly repaid.

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## PART I

### INTRODUCTORY

ABOUT the year 1895, when plans for a number of irrigation and power schemes were proposed, I computed by Kutter's formula a grill of problems to cover a large part of the work under consideration. Hydraulic canals usually traverse material that changes from solid rock to loose earth, sand or gravel, in a manner that necessitates a prompt change in the proportions and grade of the channel. The Parot Canal from the Jefferson River required, under normal conditions, a cross-sectional area of about 100 sq.ft., and my first computations were made for two degrees of roughness, three distinctive cross-sections, and four assumptions of grade, all arranged for the specific work in hand. This compilation was used with so much satisfaction that it was gradually extended to cover other work, and eventually inspired me to compute, for the office of Harper, Macdonald & Co., of Butte, a grill of problems for open channels, including everything likely to arise in our practice.

That undertaking was well advanced when all that I had prepared, together with my copy of Mr. Flynn's work, was burned in the fire that followed the San Francisco earthquake of April 18, 1906. I later had abundant reason to regard the loss of Mr. Flynn's tables as most unfortunate, as some two years passed before I was able to obtain another copy. In the meantime, while depending upon memory in re-forming my work upon a more extended scale, I failed to make a number of my grade values agree with those used by him in computing his coefficients—a circumstance that has necessitated innumerable needless interpolations, and, in some of the lowest grade columns, has introduced occasional variations in the last decimal from the results obtained by using the formula, but the widest difference observable will have no practical effect upon the rough-and-ready calculations for which the tables are especially designed.

It is not presumed that this handbook will supersede the formulas on any important work, for the prudent engineer will desire to check the results of his work in many ways, but it is confidently believed that for all preliminary and reconnaissance work, and for the general checking of hydraulic computations, the tables will serve a useful purpose, while the form in which the book appears will, I trust, be as acceptable as any yet offered for field service.

In preparing the flowage tables that follow, I have used two formulas, for closed pipes running full, to which the name of D'Arcy has been attached, four formulas for open channels usually attributed to Bazin, and an expression applicable alike to open or closed conduits, now very generally known as Kutter's formula. As the equations will all be further discussed and the results of their action more fully compared after the tables have been presented, a brief statement regarding their development will suffice at this point.

**The D'Arcy Formulas.** Engineers in general have accorded to the experiments of D'Arcy an unusual degree of confidence because of his superior equipment and eminent ability for the conduct of such work. His experiments, however, were for the most part confined to pipes of less than 20 ins. in diameter, and though the field has been somewhat extended through the work of others, the range of actual and thorough experimental confirmation still remains comparatively small, so far as I have been able to learn. Each of the D'Arcy formulas here used (see page 151) anticipates a definite degree of roughness that necessitates an abrupt change from one to another, with no means of expressing an intermediate value. The range for rugosity as described by the author is too narrow to permit a general application, but for pipes of moderate diameter, and within the limited range of roughness described, these two formulas are for good reasons highly esteemed.

**The Bazin Formulas.** D'Arcy and Bazin were, to a large extent, co-workers in the hydraulic field, and from their joint efforts four other expressions for velocity in open channels have been evolved that are generally known as the Bazin formulas. (See page 153.)

The unquestioned ability of these two authors, together with the unusual confidence of a number of excellent authorities in some of the Bazin equations, moved me to compute Tables

XIII, XIV, XV, and XVI, in order that the flowage results by his formulas might be more critically compared with those we obtain by using Kutter's expression. In doing this I have used a modified form of the Bazin expressions as being better adapted for tabular work than the original equations. Mr. Flynn gives the Brandreth modification of the fourth form, and I have followed him in reducing the first, second, and third forms (see page 154) to expressions more suitable for my immediate purpose.

As with the two by D'Arcy, so the four formulas by Bazin each assumes a specific degree of roughness that must change abruptly from one value to another, an assumption that does violence to our natural intuitions regarding the gradual increase of frictional resistance, as the walls of a conduit slowly deteriorate, or the banks of a canal gradually fall below their established order and regimen.

Bazin's fourth form is highly recommended, and is said to have been used with satisfactory results on small canals in India. His third, it appears (to judge by a comparison of the velocity curves shown in the Appendix), might be applied far more generally than the fourth, upon such slopes as are usually given to mining ditches and irrigation canals. The range within which his first or second forms can be regarded as trustworthy is comparatively small. None of the Bazin formulas, nor either of the D'Arcy equations can be regarded as *generally applicable*. (See discussion in Part VII.)

**Kutter's Formula.** Kutter's velocity formula (see page 157) was developed by Ganguillet and Kutter, from observations more numerous and general in character than those used by D'Arcy and Bazin. These observers were well equipped for work of this character, as each had attained eminence in the the engineering profession before entering upon the laborious and profitless task of deducing the equation now so generally known as Kutter's formula.

I am aware that his velocity expression has been characterized as obsolete by engineers whose attainments entitle them to much respect, and that a portion of the data from which it was evolved is said to be of questionable value; but a charge of this character can probably be sustained regarding nearly every empirical formula.

However, notwithstanding its critics and all their objections,

Kutter's formula has for years maintained its position as the most trustworthy, all-around velocity equation extant, if indeed it be not the *only* one that is entitled to that distinction. His use of a special factor  $n$ , to which numerical values for the varying degrees of rugosity have been assigned, as set forth in the following table, is the feature that renders his expression for velocity so generally applicable.

In preparing the table I have generally followed the wording of Mr. Flynn (who credits Kutter, Jackson, and Herrin), as his phrasing is usually more suggestive than the descriptions given by others.

TABLE DEFINING DEGREES OF ROUGHNESS, AND  
VALUES FOR  $n$ , AS USED IN KUTTER'S FORMULA

IN GENERAL FOR ARTIFICIAL CHANNELS

$n = .009$	well-planed timber in perfect order and alignment; otherwise perhaps .010 would be more suitable.
$n = .010$	neat cement, planed timber; and glazed, coated or enameled surfaces of every sort when smooth and true.
$n = .011$	cement mortar ( $\frac{1}{3}$ sand) in good condition; also for iron, cement and terra-cotta pipe well joined and in good order.
$n = .012$	unplaned timber well joined and flush on the inside, flumes in good order; and riveted iron and steel pipe in fair condition.
$n = .013$	ashlar and well-laid brick work; cement and terra-cotta pipes imperfectly joined; cast- and wrought-iron pipe in indifferent order; in general materials mentioned with $n = .010$ and .011 when imperfectly joined or in an inferior condition.
$n = .015$	second-class or rough-faced brick work; well-dressed stone work; foul and slightly tuberculated iron pipes; canvas lining on wooden frames; and pipe lines in general that are poorly joined and in bad order.
$n = .017$	brick work, ashlar and stoneware in an inferior condition; rubble pointed with cement mortar; tuberculated iron pipes; well-finished channels in fine gravel or earth that will retain an even face; and in general the materials mentioned with $n = .013$ when in bad order and condition.
$n = .020$	dry rubble work; stone or brick masonry in bad order; well kept canals in earth or fine gravel; and in coarse material if the spaces will fill with fine silt; and wooden flumes with battens closely nailed.

IN GENERAL FOR TORTUOUS OPEN CHANNELS AND  
NATURAL WATER-COURSES

$n = .0225$	dry rubble in bad order; canals with uniform cross-section and above the average in order and regimen.
$n = .025$	canals and rivers of tolerably uniform cross-section, slope, and direction, in moderately good order and regimen, and free from stones and weeds.
$n = .0275$	canals and rivers in earth below the average in order and regimen.
$n = .030$	canals and rivers in earth in rather bad order and regimen, having stones and weeds occasionally and somewhat obstructed by detritus.
$n = .035$	suitable for rivers and canals in bad order and regimen, overgrown with vegetation, or strewn with stones and detritus in large quantities.

The table is sometimes extended to include  $n = .050$  torrents encumbered with detritus, and  $n = .070$  rivers in earth strewn with stones and weeds in great quantities; though an attempt to estimate the resistance offered by an encumbered torrent in earth, or that offered by an aquatic growth in a conduit, seems rather impractical, aside from the misnomer involved in regarding either as an open channel in the sense in which we have been using that term.

It seems appropriate at this point to remark that the degree of roughness is usually the problematic factor in all velocity formulas. The cross-section and slope of a water-way can generally be instrumentally determined with precision, but the element of rugosity is, and must remain, a matter of individual judgment. The definitions given describe the roughness of a *surface*, but in practice there are other features beside the mere surface roughness that combine to retard the flow, as, for instance, open-butt joints, inside rivets and battens, a varying section, an uneven depth, bends and curvature, all of which conspire to make an estimate of the retarding influences a difficult task. The selection of this factor on important work is never a matter for the layman, nor for the novice in engineering; in fact, when expensive work is contemplated, counsel with the best talent and with the broadest possible experience is a sure and profitable investment.

The tables that follow are designed to facilitate computations by the formulas, but it should go without saying that

if the factors used are not correctly determined both the formulas and the tables will fail to give results that will be satisfactory.

## GENERAL ARRANGEMENT OF THE WORK

The flowage tables and those accessory thereto, numbered from I to XXVII, naturally fall into four distinct groups or *Parts*, whose fundamental difference is found in the form, or cross-section, of the conduit to which they belong. The text that precedes and that which follows the flowage tables is arranged in three *Parts*, based upon a marked difference in the subject-matter as presented. A distinguishing mark appears at the top of each page, that the reader may determine at a glance upon which of the seven *Parts* that follow the book has been opened.

Part I. Introductory.

Part II. Flowage tables for circular pipes, when running full or under pressure.

Part III. Flowage tables for rectangular open channels, or timber flumes.

Part IV. Flowage tables for open trapezoidal channels, ditches, and canals.

Part V. Egg-shaped conduits; first, when running one-third full; second, when running two-thirds full; and third, when running full.

Part VI. Miscellaneous tables, and other data convenient for field service.

Part VII. A more extended discussion of the formulas used.

Appendix. Tables comparing the coefficients of flow and a number of velocity charts contrasting the action of the various formulas.

The headlines over all flowage tables indicate the form of conduit, the formula employed, and the degree of roughness assumed. At the top, in the table headings, will be found a diminutive sketch which shows the form or cross-section upon which the area ( $a$ ), and the hydraulic radius ( $r$ ) have been calculated. The square root of the sine of the angle of inclination ( $\sqrt{s}$ ) is placed at the head of the grade columns, while the accompanying numerals give the fall in feet per mile. The diameter, or dimensions of the conduit given in feet,

the cross-sectional area given in square feet, and for all irregular forms the value of  $r$  and its square root can be found in columns on the left. At the intersection of the dimension lines with the grade columns appear, above in light-faced type the mean velocity in feet per second, and below in heavy-faced type the discharge in cubic feet per second.

An effort has been made to have every essential feature appear on every page, that the information sought may be obtained or approximated promptly, without further counsel, and without turning the leaf. When the exact dimensions and grade desired can be found in the tables, the problem is solved and the correct velocity and discharge may be read directly. However, the helpfulness of any particular table is not conditioned upon finding a channel of any specified dimensions therein, as interpolations are easily made with results that are always approximate if not exact.

## INTERPOLATIONS

The Chezy formula for velocity is,  $v = c\sqrt{r} \times \sqrt{r} \times \sqrt{s}$ , and all the velocity expressions here used may be reduced to this simple form. It is evident that when  $c$  and either  $r$  or  $s$  is constant, then  $v$  will be directly proportioned to the square root of the other factor. In both the D'Arcy and Bazin formulas the value of  $c$  is made to depend entirely upon  $r$ , and is in no wise affected by  $s$ , while with Kutter, the influence of  $s$  upon  $c$  is negligible on all slopes greater than 1 in 3000, and remains slight even though the grade be reduced as low as 1 in 5000.

With  $r$  remaining constant, we may therefore interpolate with confidence by direct proportion, for exact values of  $v$  and  $\sqrt{s}$ , from any of the flowage tables, unless the grade is lower than is usually employed in agricultural or municipal work, that is to say, less than about 1 ft. per mile.

But we *cannot* thus interpolate for *exact* values of  $v$  or the  $\sqrt{r}$  (even though  $s$  may remain constant), for any change in  $r$  will in some measure change the value of  $c$ , but as the intervals between the graduated values of  $r$  in the tables are never very great, such interpolations are always approximate and exact enough for all ordinary purposes.

Let capital letters represent the known quantities, that is, the values found in or taken from the tables, and small letters

the assumed, and unknown or required values *the algebraic*  $x$ , then any problem (for  $v$ ,  $s$ , or  $r$ ) may be proportioned after one of the following forms:

First, for values of  $v$  or  $\sqrt{s}$ , when  $r$  remains constant:

(a) For values of  $\sqrt{s}$  we have:

$$V : v :: \sqrt{S} : x = \sqrt{s}. \quad (\text{Exact result.}) \quad . . . \quad (1)$$

(b) For values of  $v$  we have,

$$\sqrt{S} : \sqrt{s} :: V : x = v. \quad (\text{Exact result.}) \quad . . . \quad (2)$$

Second, for values of  $\sqrt{r}$  or  $v$ , when  $s$  remains constant:

(a) For values of  $\sqrt{r}$  we have,

$$V : v :: \sqrt{R} : x = \sqrt{r}. \quad (\text{Approximately.}) \quad . \quad (3)$$

(b) For values of  $v$  we have,

$$\sqrt{R} : \sqrt{r} :: V : x = v. \quad (\text{Approximately.}) \quad . . \quad (4)$$

If the assumed grade or dimensions lie close to those of a channel found in the tables, nothing more than a rapid balancing of obvious conditions will as a rule be required. When, however, the proportions are radically different from anything to be found therein, calculations become necessary.

Referring again to the Chezy formula, it will further appear that all channels with a specified grade and degree of roughness, that have equivalent values of  $r$ , will develop the same velocity, though their cross-sectional area and consequent discharge may differ greatly.

When, therefore, the velocity or the discharge of a channel is desired, whose dimensions differ from anything found in the tables, compute the cross-sectional area, the hydraulic radius, and extract the square root of the latter. Then select from the table having the assumed degree of roughness, the value of  $r$  that comes nearest to the one computed and proceed to proportion for the value of  $v$  as above directed. For the discharge multiply the velocity thus obtained by the computed area.

The foregoing propositions are so rudimentary in character that it seems idle to encumber the work with examples, but a single one may be permitted if I have otherwise failed in making the method clear.

*Example.* What will be the velocity, by Kutter's formula, in a channel whose bottom width is 70 ft., with bank slopes

$1\frac{1}{2}$  to 1, with a fall of 4 ft. per mile, if the depth of water be 2 ft.  $6\frac{1}{2}$  ins. and the degree of roughness assumed as  $n=.025$ ? As the proportions of this channel differ widely from anything found in the tables, we proceed by computation to obtain the following:

$$a = 187.63 \text{ sq.ft.}; \quad p = 79.166; \quad \frac{a}{p} = r = 2.37; \quad \sqrt{2.37} = 1.54.$$

Turning now to Table XIX, in which  $n=.025$ , we find (line 31) that 1.53 is the  $\sqrt{r}$  that lies nearest the value just computed.

It is now apparent that the velocity will be about 3 ft. per second, but as no value of  $s$  in the table lies very close to 4 ft. per mile, let the interpolation proceed. In Table XXVII we find that on a grade of 4 ft. per mile the  $\sqrt{s}$  has a value of .027524, whence by form (2) on the preceding page we have the following:

$$.03162 : .027524 :: 3.29 : x = 2.86 = v,$$

exact when  $\sqrt{r} = 1.53$ .

We now approximate for  $v$  when  $\sqrt{r} = 1.54$  by form (4) as follows:

$$1.53 : 1.54 :: 2.86 : x = 2.8787 = v,$$

(approximate only), and  $(a \times v)$   $187.63 \times 2.8787 = 540.13$ , the discharge in second-feet.

The velocity is 2.876 ft. when calculated by the formula. But it may be said that the computed value of  $\sqrt{r}$  was unusually near a value found in the table. This is in a measure true and always a pleasing circumstance when it does occur, but to test the theory further, let us proportion from the next nearest value of  $\sqrt{r}$  found in the table (1.57), which will embrace a still wider interval.

Thus, by form (2)  $1.57 : 1.54 :: 2.86 : x = 2.805 = \text{velocity}$ , and  $(a \times v)$   $187.63 \times 2.805 = 526.30 = \text{discharge in second-feet}$ .

Though the above interval is unusual and unnecessary, the results approximate those obtained by using the formula.

Both judgment and discretion should be exercised in using the tables (as they have their limitations) and it should be remembered at all times that when *exact* results are required they can be very easily overworked. This applies with special force to conduits of large capacity in which it has been necessary to reduce the velocity values in the tables to one figure in decimals.

## INTRODUCING THE TABLES

Generally the dimensions of small conduits are given in inches, while those of larger channels are expressed in feet and decimals. The hydraulic radius of circular conduits is always one-fourth of the diameter. By omitting the values of  $r$  and its square root from the flowage tables for circular pipes (Part II), I have been enabled to give eight adjusted slope angles in each table instead of six, to which number all conduits in Parts III, IV, and V have been restricted.

## CIRCULAR PIPES RUNNING FULL OR UNDER PRESSURE. (PART II.)

At diameters of about  $7\frac{1}{2}$  ins. the velocity curves by Kutter, on such slopes as are usually employed, coincide with those by D'Arcy, and I append parenthetically the degree of roughness manifest in each of D'Arcy's formulas at this point, when referred to the Kutter scale.

Table I. By D'Arcy's (first) formula; for new clean cast-iron pipes running full or under pressure. (The degree of roughness is about equivalent to Kutter's  $n = .010$ ).

Table II. By D'Arcy's (second) formula; for old cast-iron pipes lined with deposit. (The degree of roughness anticipated appears to be equivalent to Kutter's  $n = .013$ ).

The four succeeding tables by Kutter give the velocity and discharge for eight graduated angles of inclination, adjusted to sixty-six varying diameters, between 5 ins. and 20 ft., and united form a substantial grill for the solution of all problems relating to the flow in circular conduits when running full or under pressure.

Table III. When the factor for roughness  $n = .010$ .

Table IV. When the factor for roughness  $n = .012$ .

Table V. When the factor for roughness  $n = .015$ .

Table VI. When the factor for roughness  $n = .020$ .

The hydraulic radius of a circular conduit when running full is always one-fourth of the diameter. It is so easily calculated from the diameter that the value of  $r$  and its square root was omitted from the flowage tables for circular pipes, in order to obtain two additional slope angles, but that these factors might be available when desired the following supplemental table has been appended to this part of the work.

Table VII gives the diameter in feet and in inches, the area in square feet, the hydraulic radius  $r$  and its square root in feet for all the diameters that are used in the tables and a large number in addition thereto. When a star appears as a reference mark it indicates that a number of worked problems for a channel of the exact dimensions given on that line will be found in the Kutter flowage tables. When a dagger appears it signifies that a line of worked problems will be found in the D'Arcy flowage tables, while if both appear it denotes that a number of solutions may be found in either of the tables named.

## RECTANGULAR OPEN CHANNELS, TIMBER FLUES. (PART III.)

Let it now be understood that the term *width*, as used here and in the tables, means *bottom* width; that *depth* means depth of *water*; that the term *area* refers to the wet or *water* area; and that in practice it will be necessary to raise the sides or banks on all open channels somewhat above the heights here given to prevent overflows and damage. The most advantageous proportions for a rectangular water-way is twice as wide as it is deep, but in timber flumes at a depth of some 5 or 6 ft. the increasing pressure near the bottom becomes a troublesome factor that usually demands an increase in the size of all dimension material used, or a closer spacing of the framed members. As this depth is approached, economy suggests that further additions to the capacity should be secured by increasing the width of the water-way more rapidly than the depth.

I have computed three flowage tables by Kutter's formula for rectangular open channels, and with a view of keeping the line of computed problems within the bounds of practical timber construction have made all flumes, 5 ft. or less in depth, twice as wide as they are deep, and have added to the width in an increasing ratio on all conduits that have a depth of more than 5 ft.

These tables present forty channels graduated in width between 4 ins. and 40 ft., each computed for six adjusted slope angles and three progressive degrees of rugosity as follows:

Table IX. When the factor for roughness  $n = .011$ .

Table X. When the factor for roughness  $n = .013$ .

Table XI. When the factor for roughness  $n = .015$ .

## FOR OPEN TRAPEZOIDAL CANALS AND DITCHES. (PART IV.)

Four flowage tables have been computed by the four different formulas of Bazin, each for thirty trapezoidal channels and six adjusted slope angles. They have been extended beyond the limits within which the equations are regarded as trustworthy, with a view of securing a more general comparison with Kutter, a fact that should be kept in mind when referring to them for any purpose whatsoever.

The degree of roughness contemplated for each formula as defined by Bazin is given below, and I append in parenthesis the range of this factor when referred to Kutter's scale, for different values of  $\sqrt{r}$  (when  $s = .0003$ , or a fall of 1.584 ft. per mile) as a feature of passing interest.

Table XIII. By Bazin's first formula. For even surfaces, fine plastered walls, planed planks, etc. (Referred to Kutter, when  $\sqrt{r} = .5$ ,  $n = .0095$  (about), when  $\sqrt{r} = 2.0$ ,  $n = .013$ , nearly, an average of about .011 for the value of  $n$ .)

Table XIV. By Bazin's second formula. For even surfaces, as cut stone, brick work, unplanned planking, mortar, etc. (Referred to Kutter, when  $\sqrt{r} = .5$ ,  $n = .012$ ; when  $\sqrt{r} = 2.0$ ,  $n = .015$ , about, an average for  $n$  of .013+.)

Table XV. By Bazin's third formula. For slightly uneven surfaces, such as rubble masonry, etc. (In this equation roughness fairly coincides with Kutter's  $n = .017$ , for the entire range.)

Table XVI. By Bazin's fourth formula. For uneven surfaces, channels in earth, etc. (Referred to Kutter, when  $\sqrt{r} = .5$ ,  $n = .030$ , when  $\sqrt{r} = 2.0$ ,  $n = .025$ , an average for  $n$  of about .0275.)

The Kutter flowage tables for trapezoidal canals are more pretentious, far more trustworthy and generally applicable than the preceding, and should be accorded the preference for all open channel work. They embrace sixty graduated conduits, with bottom widths ranging between 6 ins. and 100 ft., each computed for six adjusted slope angles and for four degrees of roughness, as follows:

Table XVII. When the factor for roughness  $n = .017$ .

Table XVIII. When the factor for roughness  $n = .020$ .

Table XIX. When the factor for roughness  $n = .025$ .

Table XX. When the factor for roughness  $n = .030$ .

In Tables VIII, XII, and XXI, the factors have been arranged to assist in an approximation and rapid solution of a line of problems of frequent occurrence, wherein the quantity or volume of the flow is the only constant factor given, all others being variable and open for mutual adjustment under such conditions as each particular location may impose.

As arranged, the quantities appear in the first column, where the flow is expressed in both second-feet and in inches, while appurtenant on the right will be found five graduated conduits, any one of which will convey the volume indicated under certain conditions. The first and the last are intended to anticipate extreme conditions, while the three intermediate capacities will usually be found in the practical realm, from which the selection made will largely depend upon whether economy in dimensions and consequent first cost, or economy in fall be the more important consideration.

Their application will be best illustrated by an example.

*Problem.* A volume of 400 sec.-ft. of water (16,000 ins.) is to be conducted over a depression to the ridge opposite; what must be the capacity of an open timber flume to accomplish the purpose?

*Solution.* Referring to Table XII, we find 375 sec.-ft. to be the nearest computed quantity, and observe that a flume 10 ft. in width carrying 5 ft. of water, on a grade of about 9 ft. to the mile, would very nearly accomplish the purpose, when the value of  $n$  is about .015. We further observe that a flume 24 ft. wide, 6.4 ft. deep, on a grade of 0.5 ft. per mile would convey somewhere near this quantity. If economy in grade be of great importance, this section might be further considered, but between these two extremes the elements are given for three other graduated capacities from which a selection may be made. Kutter's formula has been employed for the most part, though both those by D'Arcy and Bazin have been used on some of the smaller channels. A table of the character above referred to, with the features and factors so distinctly marked that no further explanation seems necessary, follows the flowage tables proper for the three forms of conduit named below.

Table VIII. For circular pipes running full or under pressure.

Table XII. For rectangular open channels and timber flumes.

Table XXI. For open trapezoidal channels, ditches, and canals.

## EGG-SHAPED CONDUITS

This form of channel is rarely used except upon sewer work, and in this service its economical employment is limited to conduits of moderate dimensions and to lines having a medium grade.

The purpose of the egg-shaped form is to secure as high a velocity as possible at low stages of the flow, thus keeping the line free from deposits, while insuring in the same channel a large carrying capacity at the high stages of its discharge. In small conduits there is but little advantage in the egg-shaped pattern, and circular pipes being more easily formed are cheaper and therefore more generally employed. For very large conduits there are other forms to which, for other reasons, a preference is usually given and in which the advantage of a small channel is secured by working one in on the bottom when required. Again; when the slope is sufficient to insure a good carrying velocity, the circular form is to be preferred; while if the slope angle be so small that a scouring velocity cannot be obtained, and some form of manual cleaning must at times be resorted to, the circular form is still preferable, as it is better adapted to the passage of every mechanical cleaning device.

The economical use of the egg-shaped pattern is therefore confined to a modest range in dimensions and to a narrow compass of slope angles. Its use is restricted almost entirely to municipal service, but within the limits thus defined it is often employed to great advantage. There are several forms, differing but little in general outline, area, or cross-section, that accomplish the same purpose, but the one shown at the head of Table XXII is now very generally used and is regarded by many municipal engineers as the standard egg pattern. The figure and the data regarding it are taken from Mr. Flynn's "Flow of Water in Irrigation Canals," and I have used his factors of  $c\sqrt{r}$ , by Kutter's formula, in calculating the velocities given in the flowage tables.

A comparison of the velocities and discharge will show the characteristic action of the fluid as the volume increases from one-third to full flow. It is interesting to note that the mean velocity is invariably higher at a two-thirds stage than it is when running full, though the discharge is greatest under the

latter conditions. When a star appears as a reference mark it indicates that a number of worked problems for a channel of the dimensions given on that line can be found in the flowage tables. After what has preceded regarding the flow in other forms, no further explanation will be needed for a full understanding and use of any of the tables named below.

Table XXII. Giving the area, the value of  $r$ , and  $\sqrt{r}$  for three different stages of the flow in egg-shaped conduits.

Table XXIII. Flowage table for egg-shaped conduits when running one-third full.

Table XXIV. Flowage table for egg-shaped conduits when running two-thirds full.

Table XXV. Flowage table for egg-shaped conduits when running full or under pressure.

#### OF THE FACTOR $r$ AND ITS SQUARE ROOT, $\sqrt{r}$ .

It should be observed that the symbol  $r$ , which is generally employed to denote the radius of a circle, one-half the diameter, is here used to indicate the *hydraulic* or mean *radius*; that is, the distance from the perimeter toward the center of a waterway where the current is moving at the *mean* velocity of the flow, its value is determined by dividing the wet or water area by the wet perimeter. The values of  $r$  and its square root have been given for all the irregular conduits used in the flowage tables, but as the  $\sqrt{r}$  is a factor that is generally required for interpolating values, in any of the tables, it seemed desirable that a much larger number than can there be found should be made available.

Table XXVI gives a large number of graduated values for  $r$  and its square root in which it will be possible to find something that will be very close to anything that can with reason be required.

#### OF THE FACTOR $s$ AND ITS SQUARE ROOT ( $\sqrt{s}$ ).

The grade, slope, or fall in a flowing body of water is measured by the angle of inclination that a line drawn between the water level at the inlet and the outlet of a closed conduit, or the water surface of an open canal, makes with the horizon. Among the Western farmers and miners it is expressed by the fall in feet per mile, or the fall in inches per rod. Technically

it is a ratio of head to distance, obtained by dividing the fall in any section by its length, the quotient being the sine of the angle of inclination, which is generally symbolized by the letter  $s$  in modern hydraulic formulas.

In the flowage tables the slope is indicated at the head of the grade columns by writing the square root of the sine of the angle of inclination ( $\sqrt{s}$ ), together with a numeral (in parenthesis) that gives the fall in feet per mile.

As the range of permissible grades from the smaller sizes of pipe to the larger channels is very great, the slopes have been graduated inversely as the capacity of the conduit, with a view to keeping the velocities within the usual limits of practice; but despite this adjustment it will often occur that intervening values are required, as no slope found in the flowage tables will be close enough to the one desired.

Table XXVII gives the ratio and percentage of the slope, the fall in feet per mile, all values of  $s$  and its square root that have been used in the tables, and a large number of intermediate values, some of which will lie reasonably near any rational grade or slope.

As the elements to be obtained from this table will be used in connection with all the tables that have preceded it, it seems appropriate to place it at the close of this part of the work.

The wide range in discharge values, from the third place in decimals to the fourth figure in whole numbers, together with the limited width of page and a desire to have all decimal points appear in a vertical line, has compelled the Author to delete the velocity values for some of the largest conduits to a single decimal. Should a more precise reading be desired, divide the discharge by the area as given and the result will usually be exact to the second and often to the third decimal place.

**PARTS II TO V**

**T A B L E S**

TABLE I.—CIRCULAR PIPES RUNNING FULL

## D'Arcy's Formula

FOR NEW CLEAN CAST-IRON PIPES

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Diam ins.	Area sq.ft.	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
			.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)	.22361 (264)	.31623 (528)
1	1	.005	.260 .001	.367 .002	.519 .003	.821 .005	1.16 0.01	1.64 0.01	2.60 0.01	3.67 0.02
2	1½	.009	.306 .003	.433 .004	.612 .005	.967 .008	1.37 0.01	1.94 0.02	3.06 0.03	4.33 0.04
3	1½	.012	.348 .004	.493 .006	.697 .009	1.102 0.014	1.56 0.02	2.20 0.03	3.48 0.04	4.93 0.06
4	1½	.017	.387 .007	.548 .009	.775 .013	1.225 0.021	1.73 0.03	2.45 0.04	3.87 0.07	4.48 0.09
5	2	.022	.424 .009	.600 .013	.848 .019	1.341 0.029	1.90 0.04	2.68 0.06	4.24 0.09	6.00 0.13
6	2½	.034	.491 .017	.694 .024	.981 .034	1.551 0.053	2.19 0.08	3.10 0.11	4.91 0.17	6.94 0.24
7	3	.049	.551 .027	.779 .038	1.102 0.054	1.742 0.086	2.46 0.12	3.48 0.17	5.51 0.27	7.79 0.38
8	4	.087	.657 .057	.929 .081	1.314 0.115	2.077 0.181	2.94 0.26	4.15 0.36	6.57 0.57	9.29 0.81
9	5	.136	.750 .102	1.061 0.145	1.500 0.204	2.372 0.323	3.35 0.46	4.74 0.65	7.50 1.02	10.61 1.45
10	6	.196	.834 .164	1.179 0.232	1.667 0.327	2.636 0.518	3.73 0.73	5.27 1.04	8.34 1.64	11.79 2.32
11	7	.267	.58 .15	.91 .24	1.29 0.34	1.82 0.49	2.87 0.77	4.07 1.09	5.75 1.54	9.09 2.42
12	8	.349	.62 .22	.98 .34	1.38 0.48	1.96 0.68	3.09 1.08	4.38 1.53	6.19 2.16	9.78 3.42
13	9	.442	.66 .29	1.05 0.46	1.48 0.65	2.09 0.92	3.30 1.46	4.67 2.07	6.61 2.92	10.45 4.62
14	10	.545	.70 .38	1.11 0.60	1.56 0.85	2.21 1.21	3.50 1.91	4.95 2.70	6.99 3.81	11.06 6.03
15	12	.785	.77 .61	1.22 0.96	1.73 1.36	2.44 1.92	3.86 3.04	5.47 4.29	7.73 6.07	12.22 9.60
16	14	1.069	.84 .90	1.33 1.42	1.88 2.01	2.65 2.84	4.20 4.49	5.93 6.34	8.39 8.97	13.27 14.19
17	16	1.396	.90 1.26	1.42 1.99	2.01 2.81	2.85 3.97	4.50 6.29	6.37 8.89	9.00 12.57	14.24 19.83
18	18	1.767	.96 1.69	1.52 2.68	2.14 3.79	3.03 5.35	4.79 8.47	6.78 11.97	9.58 16.93	15.15 26.77
19	20	2.182	1.01 2.21	1.60 3.50	2.27 4.95	3.21 7.00	5.07 11.07	7.17 15.65	10.14 22.13	16.04 34.99
20	22	2.640	1.07 2.81	1.68 4.45	2.38 6.29	3.37 8.89	5.33 14.06	7.53 19.88	10.65 28.12	16.84 44.46

TABLE I.—CIRCULAR PIPES RUNNING FULL (Con.)

## D'Arcy's Formula

FOR NEW CLEAN CAST-IRON PIPES

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



C Z	Diam Area		Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
	ft. in.	sq. ft.	.01000 (.528)	.01414 (1.06)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)
21	2	3.14	.79 2.48	1.11 3.50	1.76 5.54	2.49 7.83	3.52 11.07	5.57 17.51	7.88 24.76	11.14 35.01
22	2 3	3.98	.84 3.33	1.19 4.71	1.87 7.45	2.65 10.53	3.75 14.89	5.92 23.55	8.38 33.31	11.85 47.10
23	2 6	4.91	.88 4.34	1.25 6.14	1.98 9.70	2.80 13.72	3.95 19.41	6.25 30.68	8.84 43.39	12.50 61.36
24	2 9	5.94	.93 5.52	1.31 7.80	2.08 12.34	2.94 17.45	4.16 24.68	6.57 39.01	9.29 55.17	13.14 78.03
25	3	7.07	.97 6.87	1.37 9.71	2.17 15.36	3.07 21.72	4.35 30.72	6.87 48.56	9.72 68.68	13.74 97.13
26	3 4	8.73	1.03 8.95	1.45 12.66	2.29 20.02	3.25 28.32	4.59 40.04	7.26 63.31	10.26 89.53	14.51 126.61
27	3 8	10.56	1.08 11.36	1.52 16.07	2.41 25.41	3.40 35.93	4.81 50.81	7.61 80.33	10.76 113.62	15.22 160.68
28	4	12.57	1.13 14.15	1.59 20.01	2.52 31.64	3.56 44.75	5.04 63.28	7.96 100.05	11.26 141.49	15.92 200.10
29	4 6	15.90	1.20 19.02	1.69 26.89	2.67 42.53	3.78 60.15	5.35 85.07	8.46 134.50	11.96 190.21	16.91 269.00
30	5	19.64	1.26 24.76	1.78 35.01	2.82 55.37	3.99 78.30	5.64 110.72	8.92 175.09	12.61 247.60	17.83 350.15
31	6	28.3	.98 27.68	1.38 39.13	2.0 55.3	3.1 87.5	4.4 123.7	6.2 175.0	9.8 276.7	13.8 391.3
32	7	38.5	1.06 40.72	1.50 57.58	2.1 81.4	3.4 128.7	4.7 182.1	6.7 257.5	10.6 407.1	15.0 575.8
33	8	50.3	1.13 56.86	1.60 80.43	2.3 113.8	3.6 179.9	5.1 254.4	7.2 359.7	11.3 568.8	16.0 804.3
34	9	63.6	1.20 76.41	1.70 108.08	2.4 152.8	3.8 241.6	5.4 341.6	7.6 483.1	12.0 763.9	17.0 1080.3
35	10	78.5	1.27 99.43	1.79 140.67	2.5 198.9	4.0 314.6	5.7 444.9	8.0 629.1	12.7 994.6	17.9 1406.7
36	12	113.1	1.39 156.98	1.96 222.02	2.8 314.0	4.4 496.4	6.2 702.1	8.8 992.9	13.9 1569.8	19.6 2220.2
37	14	153.9	1.50 230.91	2.12 326.66	3.0 462.0	4.7 730.4	6.7 1032.9	9.5 1460.9	15.0 2309.9	21.2 3266.6
38	16	201.1	1.60 322.50	2.27 456.21	3.2 645.2	5.1 1020.2	7.2 1442.6	10.1 2040.2	16.0 3225.8	22.7 4562.1
39	18	254.5	1.70 433.11	2.41 612.51	3.4 866.2	5.4 1369.6	7.6 1937.0	10.8 2739.1	17.0 4331.1	24.1 6125.1
40	20	314.2	1.80 563.92	2.54 797.34	3.6 1127.5	5.7 1782.9	8.0 2521.4	11.4 3565.7	17.9 5637.9	25.4 7973.4

TABLE II.—CIRCULAR PIPES RUNNING FULL

## D'Arcy's Formula

FOR OLD CAST-IRON PIPES LINED WITH DEPOSIT



Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.

No.	Diam ins.	Area sq. ft.	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
			.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)	.22361 (264)	.31623 (528)	.44721 (1056)
1	1	.005	.247 .001	.349 .002	.552 .003	.781 .004	1.11 0.01	1.75 0.01	2.47 0.01	3.49 0.02
2	1½	.009	.293 .003	.414 .004	.654 .006	.926 .008	1.31 0.01	2.07 0.02	2.93 0.03	4.14 0.04
3	1½	.012	.331 .004	.469 .006	.741 .009	1.048 0.013	1.48 0.02	2.34 0.03	3.31 0.04	4.69 0.06
4	1¾	.017	.368 .006	.521 .009	.824 .014	1.165 0.020	1.65 0.03	2.61 0.04	3.68 0.06	5.21 0.09
5	2	.022	.403 .009	.570 .012	.902 .020	1.275 0.028	1.80 0.04	2.85 0.06	4.03 0.09	5.70 0.12
6	2½	.034	.467 .016	.660 .023	1.044 0.036	1.476 0.050	2.09 0.07	3.30 0.11	4.67 0.16	6.60 0.23
7	3	.049	.524 .026	.741 .036	1.171 0.058	1.656 0.081	2.34 0.12	3.70 0.18	5.24 0.26	7.41 0.36
8	4	.087	.625 .055	.883 .077	1.397 0.122	1.975 0.172	2.79 0.24	4.42 0.39	6.25 0.55	8.83 0.77
9	5	.136	.713 .097	1.009 0.138	1.595 0.217	2.256 0.308	3.19 0.44	5.05 0.69	7.13 0.97	10.09 1.38
10	6	.196	.793 .156	1.121 0.220	1.773 0.348	2.507 0.492	3.55 0.70	5.61 1.10	7.93 1.56	11.21 2.20
<hr/>										
	ins.	sq. ft.	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)	.22361 (264)	.31623 (528)
11	7	.267	.61 .16	.87 .23	1.22 0.33	1.93 0.52	2.73 0.73	3.87 1.03	6.11 1.63	8.65 2.31
12	8	.349	.66 .23	.93 .33	1.32 0.46	2.08 0.73	2.94 1.03	4.16 1.45	6.58 2.30	9.31 3.25
13	9	.442	.70 .31	.99 .44	1.41 0.62	2.22 0.98	3.14 1.39	4.44 1.96	7.03 3.10	9.94 4.39
14	10	.545	.74 .41	1.05 0.57	1.49 0.81	2.35 1.28	3.33 1.81	4.70 2.57	7.44 4.06	10.52 5.74
15	12	.785	.82 .65	1.16 0.91	1.64 1.29	2.60 2.04	3.68 2.89	5.20 4.08	8.22 6.45	11.62 9.13
16	14	1.069	.89 .95	1.26 1.35	1.79 1.91	2.82 3.02	3.99 4.27	5.64 6.03	8.92 9.54	12.62 13.49
17	16	1.396	.96 1.34	1.35 1.89	1.92 2.67	3.03 4.23	4.28 5.98	6.06 8.46	9.58 13.37	13.54 18.91
18	18	1.767	1.02 1.80	1.44 2.55	2.04 3.60	3.22 5.69	4.56 8.05	6.45 11.39	10.19 18.01	14.41 25.46
19	20	2.182	1.08 2.36	1.53 3.34	2.16 4.72	3.42 7.46	4.83 10.55	6.84 14.92	10.81 23.59	15.29 33.35
20	22	2.640	1.13 2.99	1.60 4.23	2.27 5.98	3.58 9.46	5.07 13.37	7.16 18.91	11.33 29.91	16.02 42.29

TABLE II.—CIRCULAR PIPES RUNNING FULL (Con.)

## D'Arcy's Formula

FOR OLD CAST-IRON PIPES LINED WITH DEPOSIT

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Diam. ft. in.	Area sq. ft.	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
			.01414 (1.06)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)	.22361 (264)
21	2	3.14	.75	1.18	1.68	2.37	3.75	5.30	7.49	11.84
22	2 3	3.98	2.35	3.72	5.26	7.44	11.77	16.64	23.53	37.21
23	2 6	4.91	.80	1.26	1.78	2.52	3.99	5.64	7.97	12.60
24	2 9	5.94	3.17	5.01	7.09	10.02	15.84	22.41	31.69	50.10
25	3	7.07	.84	1.33	1.88	2.66	4.20	5.95	8.41	13.30
26	3 4	8.73	4.13	6.53	9.23	13.05	20.64	29.19	41.23	65.27
27	3 8	10.56	.88	1.40	1.98	2.80	4.42	6.25	8.84	13.97
28	4	12.57	5.25	8.30	11.74	16.60	26.24	37.11	52.48	82.99
29	4 6	15.90	.92	1.46	2.07	2.92	4.62	6.54	9.24	14.61
30	5	19.64	6.53	10.33	14.61	20.66	32.66	46.19	65.32	103.29
31	6	28.3	.98	1.54	2.18	3.09	4.88	6.90	9.76	15.43
32	7	38.5	8.82	13.46	19.04	26.93	42.57	60.21	85.15	134.63
33	8	50.3	1.02	1.62	2.29	3.24	5.12	7.24	10.24	16.19
34	9	63.6	10.81	17.10	24.18	34.19	54.05	76.45	108.11	170.94
35	10	78.5	1.07	1.69	2.40	3.39	5.36	7.57	10.71	16.93
36	12	113.1	13.46	21.27	30.10	42.56	67.29	95.16	134.58	212.79
37	14	153.9	1.14	1.80	2.54	3.60	5.69	8.04	11.37	17.99
38	16	201.1	18.08	28.60	40.44	57.21	90.45	127.92	180.98	286.03
39	18	254.5	1.20	1.90	2.68	3.79	6.00	8.49	12.00	18.97
40	20	314.2	23.56	37.25	52.68	74.50	117.77	166.56	235.56	372.46
41	22	380.1	.93	1.32	2.1	2.9	4.2	6.6	9.3	13.2
42	24	452.4	26.32	37.20	58.8	83.2	117.7	166.1	235.1	372.1
43	26	531.6	1.01	1.42	2.3	3.2	4.5	7.1	10.1	14.2
44	28	617.8	38.72	54.77	86.6	122.5	173.2	273.8	387.2	547.6
45	30	710.6	1.08	1.52	2.4	3.4	4.8	7.6	10.8	15.2
46	32	810.1	54.09	76.51	121.0	171.1	241.9	382.5	541.0	765.0
47	34	916.3	1.14	1.62	2.6	3.6	5.1	8.1	11.4	16.2
48	36	1029.5	72.65	102.75	162.5	229.7	324.9	513.7	726.5	1027.5
49	38	1149.7	1.20	1.70	2.7	3.8	5.4	8.5	12.0	17.0
50	40	1276.9	94.56	133.75	211.4	299.0	422.9	668.6	945.6	1337.3
51	42	1412.1	1.32	1.87	3.0	4.2	5.9	9.3	13.2	18.7
52	44	1555.3	149.29	211.16	333.9	472.1	667.6	1055.7	1492.9	2111.4
53	46	1706.5	1.43	2.02	3.2	4.5	6.4	10.1	14.3	20.2
54	48	1865.7	219.67	310.65	491.2	694.7	982.4	1553.3	2196.7	3106.7
55	50	2032.9	1.53	2.16	3.4	4.8	6.8	10.8	15.3	21.6
56	52	2208.1	306.82	433.89	686.0	970.3	1372.0	2169.4	3068.2	4339.1
57	54	2391.3	1.62	2.29	3.6	5.1	7.2	11.4	16.2	22.9
58	56	2582.5	411.99	582.74	921.2	1302.9	1842.4	2913.2	4119.9	5826.3
59	58	2781.7	1.71	2.41	3.8	5.4	7.6	12.1	17.1	24.1
60	60	3088.9	536.27	758.38	1199.1	1695.8	2398.3	3791.9	5362.7	7584.1

TABLE III.—CIRCULAR PIPES RUNNING FULL

## Kutter's Formula

When  $n$  equals .010.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Diam		Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
	ft. in.	sq.ft.	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)	.22361 (264)	.31623 (528)
1	5	.136	.661 0.090	.966 1.32	1.366 0.186	2.159 0.294	3.054 0.416	4.32 0.59	6.83 0.93	9.66 1.32
2	6	.196	.763 1.150	1.114 0.219	1.576 0.310	2.491 0.489	3.523 0.692	4.98 0.98	7.88 1.55	11.14 2.19
3	7	.267	.861 1.230	1.256 0.336	1.777 0.475	2.809 0.751	3.973 1.062	5.62 1.50	8.88 2.38	12.56 3.36
4	8	.349	.955 1.333	1.392 0.486	1.969 0.687	3.113 1.087	4.403 1.537	6.23 2.17	9.85 3.44	13.92 4.86
5	9	.442	1.045 0.462	1.521 0.672	2.151 0.950	3.400 1.502	4.809 2.125	6.80 3.01	10.75 4.75	15.21 6.72
6	10	.545	1.131 0.617	1.643 0.896	2.324 1.268	3.674 2.004	5.196 2.834	7.35 4.01	11.62 6.34	16.43 8.96
7	11	.660	1.219 0.805	1.770 1.168	2.503 1.652	3.958 2.612	5.597 3.694	7.92 5.22	12.52 8.26	17.70 11.68
8	1	.785	1.303 1.023	1.889 1.484	2.672 2.099	4.225 3.318	5.975 4.693	8.45 6.64	13.36 10.49	18.90 14.84
9	1	.922	1.379 1.271	1.998 1.842	2.826 2.605	4.468 4.119	6.319 5.825	8.94 8.24	14.13 13.03	19.98 18.42
10	1	2	1.069 1.558	2.110 2.256	2.983 3.189	4.717 5.042	6.671 7.131	9.43 10.09	14.92 15.95	21.10 22.55
11	1	3	1.227 1.533 1.881	2.218 2.218 2.722	3.136 3.136 3.848	4.959 4.959 6.086	7.013 7.013 8.606	9.92 9.92 12.17	15.68 15.68 19.25	22.18 22.18 27.22
	ft. in.	sq.ft.	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)
12	1	4	1.396 1.87	1.10 1.53	1.61 2.24	2.32 3.24	3.28 4.58	5.19 7.25	7.34 10.25	10.39 14.50
13	1	6	1.767 1.95	1.20 2.12	1.75 3.09	2.53 4.47	3.58 6.32	5.65 9.99	7.99 14.12	11.30 19.97
14	1	8	2.182 1.03	1.30 2.83	1.89 4.13	2.73 5.95	3.86 8.41	6.10 13.30	8.62 18.81	12.19 26.61
15	1	10	2.640 1.11	1.39 2.92	2.02 5.34	2.91 7.69	4.12 10.88	6.51 17.20	9.21 24.32	13.03 34.39
16	2	3.142	1.18 3.70	1.48 4.65	2.15 6.76	3.10 9.73	4.38 13.76	6.92 21.75	9.79 30.76	13.85 48.51
17	2	2	3.687 4.61	1.57 5.78	2.28 8.39	3.27 12.06	4.63 17.05	7.31 26.96	10.34 38.13	14.63 53.93
18	2	4	4.276 1.32	1.65 2.40	2.40 3.44	3.44 4.87	4.87 7.70	7.70 10.89	10.89 15.39	15.39 22.18
19	2	6	4.909 6.80	1.73 8.51	2.51 12.33	3.61 17.70	5.10 28.03	8.06 39.57	11.40 55.96	16.12 79.14
20	2	8	5.585 1.45	1.82 2.63	2.63 3.77	3.77 5.34	5.34 8.44	8.44 11.93	11.93 16.87	16.87 22.18
21	2	10	6.305 1.52	1.90 2.74	2.74 3.93	3.93 5.56	5.56 8.78	8.78 12.42	12.42 17.57	17.57 22.18
22	3	7.068	1.58 11.16	1.97 13.94	2.85 20.12	4.08 28.83	5.77 40.78	9.12 64.47	12.90 91.18	18.24 128.94

TABLE III.—CIRCULAR PIPES RUNNING FULL (Con.)

## Kutter's Formula

When  $n$  equals .010.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Diam		Area	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
	ft.	in.	sq.ft.	.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)
23	3	2	7.88	1.25 9.85	1.42 11.20	1.64 12.93	2.05 16.14	2.96 23.27	4.23 33.34	5.99 47.14	9.47 74.54
24	3	4	8.73	1.30 11.33	1.47 12.86	1.70 14.85	2.12 18.53	3.06 26.69	4.38 38.21	6.19 54.04	9.79 86.45
25	3	6	9.62	1.34 12.91	1.52 14.66	1.76 16.93	2.19 21.10	3.16 30.38	4.52 43.48	6.39 61.48	10.10 97.21
26	3	8	10.56	1.39 14.66	1.57 16.62	1.82 19.20	2.26 23.91	3.26 34.40	4.66 49.19	6.59 69.57	10.42 110.00
27	3	10	11.54	1.43 16.55	1.63 18.75	1.88 21.66	2.34 26.95	3.36 38.77	4.80 55.42	6.79 78.38	10.74 123.92
28	4		12.57	1.48 18.57	1.68 21.05	1.93 24.30	2.41 30.22	3.46 43.44	4.94 62.08	6.99 87.77	11.05 138.79
29	4	2	13.64	1.52 20.74	1.72 23.49	1.99 27.12	2.47 33.72	3.55 48.43	5.07 69.18	7.18 97.83	11.35 154.69
30	4	4	14.75	1.56 23.05	1.77 26.09	2.04 30.13	2.54 37.43	3.64 53.74	5.20 76.73	7.36 108.50	11.63 171.56
31	4	6	15.90	1.61 25.53	1.82 28.88	2.10 33.35	2.60 41.41	3.74 59.42	5.33 84.82	7.54 119.95	11.93 189.66
32	4	9	17.72	1.67 29.51	1.88 33.35	2.17 38.53	2.70 47.79	3.87 68.51	5.52 97.77	7.80 138.26	12.34 218.61
33	5		19.64	1.73 33.91	1.95 38.31	2.25 44.24	2.79 54.84	4.00 78.56	5.71 112.04	8.07 158.45	12.76 250.54
34	5	3	21.65	1.38 29.92	1.57 33.99	1.79 38.69	2.02 43.66	2.33 50.42	2.89 62.48	4.13 89.45	5.89 127.49
35	5	6	23.76	1.43 33.95	1.62 38.56	1.85 43.83	2.08 49.46	2.40 57.11	2.98 70.70	4.26 101.19	6.07 144.14
35	5	9	25.97	1.47 38.28	1.68 43.50	1.90 49.39	2.15 55.70	2.48 64.32	3.06 79.56	4.38 113.81	6.24 162.03
37	6		28.27	1.52 42.95	1.73 48.80	1.96 55.36	2.21 62.40	2.55 72.07	3.15 89.12	4.50 127.35	6.41 181.24
38	6	3	30.68	1.56 47.95	1.78 54.46	2.01 61.76	2.27 69.55	2.62 80.32	3.24 99.28	4.62 141.80	6.58 201.75
39	6	6	33.18	1.61 53.33	1.83 60.56	2.07 68.59	2.33 77.25	2.69 89.20	3.32 110.23	4.74 157.32	6.74 223.72
40	6	9	35.79	1.65 59.05	1.87 67.06	2.12 75.90	2.39 85.42	2.76 98.62	3.40 121.81	4.86 173.74	6.90 247.06
41	7		38.49	1.69 65.12	1.92 73.97	2.17 83.63	2.45 94.10	2.82 108.64	3.49 134.16	4.97 191.23	7.06 271.82
42	7	3	41.28	1.73 71.54	1.97 81.28	2.22 91.77	2.50 103.25	2.89 119.22	3.56 147.13	5.08 209.63	7.22 297.89
43	7	6	44.18	1.77 78.37	2.02 89.02	2.27 100.46	2.56 112.97	2.95 130.46	3.64 160.94	5.19 229.20	7.37 325.60
44	7	9	47.17	1.82 85.67	2.06 97.32	2.33 109.72	2.61 123.31	3.02 142.42	3.72 175.58	5.30 249.97	7.53 354.98

TABLE III.—CIRCULAR PIPES RUNNING FULL (Con.)

## Kutter's Formula

When  $n$  equals .010.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Diam. ft. in.	Area sq.ft.	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
			.00707 (.264)	.00791 (.33)	.00898 (.426)	.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)
45	8	50.27	1.65 82.85	1.86 93.30	2.11 105.97	2.38 119.39	2.67 134.17	3.08 154.88	3.80 190.88	5.40 271.61
46	8 3	53.46	1.68 90.03	1.90 101.36	2.15 115.10	2.42 129.59	2.72 145.57	3.14 168.08	3.87 207.05	5.51 294.40
47	8 6	56.75	1.72 97.61	1.94 109.87	2.20 124.79	2.47 140.34	2.78 157.60	3.21 182.00	3.95 224.11	5.61 318.48
48	8 9	60.13	1.76 105.53	1.98 118.76	2.24 134.87	2.52 151.53	2.83 170.17	3.27 196.51	4.02 241.84	5.71 343.46
49	9	63.62	1.79 113.88	2.01 128.13	2.29 146.50	2.57 163.38	2.88 183.42	3.33 211.79	4.10 260.59	5.82 370.21
50	9 3	67.20	1.83 122.64	2.05 137.39	2.33 156.58	2.62 175.73	2.94 197.23	3.39 227.74	4.17 280.09	5.92 397.82
51	9 6	70.88	1.86 131.77	2.09 148.00	2.37 168.13	2.66 188.54	2.98 211.51	3.45 244.25	4.24 300.39	6.02 426.49
52	9 9	74.66	1.89 141.26	2.13 158.65	2.41 180.23	2.71 202.03	3.03 226.53	3.50 261.61	4.31 321.64	6.11 456.40
53	10	78.54	1.93 151.27	2.16 169.80	2.46 192.89	2.75 216.14	3.08 242.22	3.56 279.68	4.38 343.85	6.21 487.81
54	10 6	86.59	1.99 172.49	2.23 193.44	2.54 219.77	2.84 246.00	3.18 275.53	3.67 318.13	4.51 390.87	6.40 554.18
55	11	95.03	2.06 195.48	2.31 219.04	2.62 245.79	2.93 278.15	3.28 311.41	3.78 359.59	4.65 441.60	6.58 625.68
56	11 6	103.9	1.90 197.15	2.12 220.41	2.4 246.9	2.7 280.4	3.0 313.2	3.4 350.4	3.9 404.6	4.8 496.6
57	12	113.1	1.95 220.88	2.18 246.90	2.4 276.4	2.8 314.0	3.1 350.3	3.5 391.7	4.0 452.3	4.9 554.9
58	12 6	122.7	2.01 246.42	2.25 275.51	2.5 308.2	2.9 350.0	3.2 390.3	3.6 436.3	4.1 503.8	5.0 617.7
59	13	132.7	2.06 273.69	2.31 305.94	2.6 342.0	2.9 388.5	3.3 432.8	3.6 483.7	4.2 558.5	5.2 684.4
60	14	153.9	2.17 333.59	2.42 373.00	2.7 416.7	3.1 473.2	3.4 526.3	3.8 587.6	4.4 678.6	5.4 830.8
61	15	176.7	2.27 400.80	2.54 448.16	2.8 500.3	3.2 568.2	3.6 630.9	4.0 703.9	4.6 812.9	5.6 994.6
62	16	201.1	2.37 476.31	2.65 532.61	3.0 593.9	3.4 674.6	3.7 747.9	4.1 832.9	4.8 963.1	5.9 1177.4
63	17	227.0	2.47 559.51	2.76 625.56	3.1 697.1	3.5 791.7	3.9 876.6	4.3 977.1	5.0 1128.3	6.1 1378.9
64	18	254.5	2.56 651.70	2.86 728.55	3.2 810.7	3.6 920.9	4.0 1018.9	4.5 1135.2	5.2 1310.8	6.3 1600.6
65	19	283.5	2.66 752.77	2.97 841.52	3.3 935.9	3.7 1063.0	4.1 1174.7	4.6 1308.2	5.3 1510.6	6.5 1843.5
66	20	314.2	2.74 862.06	3.07 963.84	3.4 1071.0	3.9 1216.7	4.3 1343.3	4.8 1494.8	5.5 1726.3	6.7 2108.5

TABLE IV.—CIRCULAR PIPES RUNNING FULL

## Kutter's Formula

When  $n$  equals .012.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



C	Diam ft. in.	Area sq.ft.	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
			.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)	.22361 (264)	.31623 (528)
1	5	.136	.511 .070	.749 .102	1.060 0.144	1.676 0.228	2.370 0.323	3.352 0.457	5.30 0.72	7.50 1.02
2	6	.196	.594 .117	.868 .170	1.228 0.241	1.941 0.381	2.745 0.539	3.882 0.762	6.14 1.21	8.68 1.71
3	7	.267	.673 .180	.982 .262	1.389 0.371	2.196 0.587	3.105 0.830	4.391 1.174	6.94 1.86	9.82 2.63
4	8	.349	.749 .261	1.091 0.381	1.543 0.539	2.440 0.852	3.451 1.205	4.880 1.704	7.72 2.69	10.91 3.81
5	9	.442	.821 .363	1.195 0.528	1.690 0.747	2.673 1.181	3.780 1.670	5.346 2.362	8.45 3.73	11.95 5.28
6	10	.545	.890 .485	1.295 0.706	1.831 0.999	2.896 1.579	4.095 2.233	5.791 3.158	9.16 4.99	12.95 7.08
7	11	.660	.962 .635	1.398 0.923	1.978 1.305	3.127 2.064	4.422 2.919	6.254 4.128	9.89 6.53	13.98 9.23
8	1	.785	1.030 0.809	1.496 1.175	2.115 1.661	3.345 2.627	4.730 3.715	6.689 5.254	10.58 8.31	14.96 11.78
9	1	1	1.092 1.007	1.585 1.461	2.241 2.066	3.543 3.266	5.011 4.619	7.087 6.533	11.20 10.33	15.85 14.61
10	1	2	1.156 1.236	1.676 1.792	2.370 2.534	3.747 4.006	5.299 5.665	7.494 8.011	11.85 12.67	16.76 17.91
11	1	3	1.218 1.495	1.764 2.165	2.495 3.062	3.944 4.840	5.578 6.845	7.888 9.680	12.47 15.31	17.64 21.65
	ft. in.	sq.ft.	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)
12	1	4	1.396 .963	.87 1.22	1.28 1.79	1.85 2.58	2.62 3.65	4.14 5.77	5.85 8.17	8.27 11.55
13	1	6	1.767 1.338	.96 1.69	1.40 2.47	2.02 3.87	2.86 5.05	4.51 7.97	6.38 11.28	9.03 16.96
14	1	8	2.182 1.794	1.04 2.26	1.51 3.30	2.18 4.76	3.09 6.74	4.88 10.65	6.90 15.06	9.76 21.30
15	1	10	2.640 2.334	1.11 2.94	1.62 4.28	2.34 6.17	3.31 8.73	5.23 13.80	7.39 19.51	10.45 27.59
16	2	3.142	.945 2.969	1.19 3.73	1.73 5.43	2.49 7.82	3.52 11.06	5.57 17.49	7.87 24.73	11.13 34.98
17	2	3.687	1.003 3.698	1.26 4.64	1.83 6.75	2.63 9.71	3.73 13.73	5.89 21.71	8.33 30.71	11.78 43.43
18	2	4.276	1.061 4.537	1.33 5.69	1.93 8.26	2.78 11.87	3.93 16.79	6.21 26.55	8.78 37.55	12.42 53.10
19	2	4.909	1.116 5.478	1.40 6.86	2.03 9.95	2.91 14.30	4.12 20.22	6.51 31.97	9.21 48.21	13.02 63.93
20	2	5.585	1.173 6.551	1.47 8.20	2.13 11.88	3.05 17.05	4.32 24.11	6.83 38.12	9.65 53.91	13.65 76.24
21	2	10	6.305 7.730	1.53 9.67	2.22 13.98	3.18 20.06	4.50 28.37	7.12 44.87	10.06 63.45	14.23 89.73
22	3	7.068	1.277 9.026	1.60 11.28	2.31 16.31	3.31 23.39	4.68 33.08	7.40 52.30	10.46 73.96	14.80 104.59

TABLE IV.—CIRCULAR PIPES RUNNING FULL (Con.)

## Kutter's Formula

When  $n$  equals .012.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Diam		Area	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
	ft.	in.	sq.ft.	.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)
23	3	2	7.88	1.01 7.97	1.15 9.07	1.33 10.47	1.66 13.07	2.40 18.89	3.44 27.07	4.86 38.29	7.69 60.54
24	3	4	8.73	1.05 9.17	1.20 10.43	1.38 12.04	1.72 15.03	2.49 21.68	3.56 31.07	5.04 43.94	7.96 69.47
25	3	6	9.62	1.09 10.47	1.24 11.90	1.43 13.74	1.78 17.14	2.57 24.71	3.68 35.37	5.20 50.02	8.22 79.09
26	3	8	10.56	1.13 11.89	1.28 13.51	1.48 15.60	1.84 19.43	2.65 27.99	3.80 40.07	5.37 56.67	8.49 89.59
27	3	10	11.54	1.16 13.43	1.32 15.26	1.53 17.61	1.90 21.94	2.74 31.53	3.91 45.17	5.54 63.88	8.75 101.00
28	4		12.57	1.20 15.09	1.36 17.13	1.57 19.78	1.96 24.62	2.82 35.40	4.03 50.63	5.70 71.59	9.01 113.20
29	4	2	13.04	1.24 16.87	1.40 19.13	1.62 22.10	2.02 27.49	2.90 39.51	4.14 56.48	5.86 79.87	9.26 136.29
30	4	4	14.75	1.27 18.76	1.44 21.28	1.67 24.57	2.07 30.53	2.98 43.88	4.25 62.69	6.01 88.65	9.51 140.18
31	4	6	15.90	1.31 20.80	1.48 23.57	1.71 27.21	2.13 33.81	3.05 48.56	4.36 69.34	6.17 98.08	9.75 155.06
32	4	9	17.72	1.36 24.07	1.54 27.26	1.78 31.47	2.20 39.06	3.16 56.07	4.52 80.03	6.39 113.18	10.10 178.95
33	5		19.64	1.41 27.69	1.60 31.34	1.84 36.19	2.29 44.87	3.28 64.34	4.68 91.81	6.61 129.85	10.46 205.30
<hr/>											
	ft.	in.	sq.ft.	.00791 (.33)	.00898 (.426)	.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)
34	5	3	21.65	1.13 24.44	1.28 27.75	1.46 31.63	1.65 35.76	1.91 41.28	2.36 51.15	3.39 73.32	4.83 104.58
35	5	6	23.76	1.17 27.75	1.33 31.53	1.51 35.88	1.71 40.53	1.97 46.80	2.44 57.97	3.50 83.03	4.98 118.36
36	5	9	25.97	1.21 31.34	1.37 35.60	1.56 40.46	1.76 45.70	2.03 52.77	2.52 65.31	3.60 93.48	5.13 133.19
37	6		28.27	1.25 35.20	1.41 39.98	1.61 45.38	1.81 51.23	2.09 59.15	2.59 73.20	3.70 104.67	5.27 149.06
38	6	3	30.68	1.28 39.33	1.46 44.67	1.65 50.65	1.86 57.16	2.15 65.99	2.66 81.61	3.80 116.62	5.41 166.04
39	6	6	33.18	1.32 43.80	1.50 49.74	1.70 56.35	1.91 63.51	2.21 73.37	2.73 90.69	3.90 129.48	5.55 184.23
40	6	9	35.79	1.36 48.52	1.54 55.11	1.74 62.38	1.96 70.28	2.27 81.16	2.80 100.31	4.00 143.10	5.69 203.55
41	7		38.49	1.39 53.57	1.58 60.85	1.79 68.77	2.01 77.51	2.33 89.48	2.87 110.53	4.10 157.60	5.82 224.10
42	7	3	41.28	1.43 58.91	1.62 66.92	1.83 75.59	2.06 85.08	2.38 98.25	2.94 121.29	4.19 172.85	5.95 245.79
43	7	6	44.18	1.46 64.59	1.66 73.34	1.87 82.79	2.11 93.17	2.44 107.58	3.01 132.76	4.28 189.13	6.09 268.87
44	7	9	47.17	1.50 70.62	1.70 80.24	1.92 90.48	2.16 101.75	2.49 117.51	3.07 144.96	4.38 206.38	6.22 293.33

TABLE IV.—CIRCULAR PIPES RUNNING FULL (Con.)

## Kutter's Formula

When  $n$  equals .012.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Diam ft. in.	Area sq.ft.	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
			.00707 (.264)	.00791 (.33)	.00898 (.426)	.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)
45	8	50.27	1.36 <b>68.32</b>	1.53 <b>76.96</b>	1.74 <b>87.42</b>	1.96 <b>98.53</b>	2.20 <b>110.75</b>	2.54 <b>127.89</b>	3.14 <b>157.70</b>	4.47 <b>224.46</b>
46	8 3	53.46	1.39 <b>74.26</b>	1.57 <b>83.67</b>	1.78 <b>95.00</b>	2.00 <b>106.97</b>	2.25 <b>120.23</b>	2.60 <b>136.84</b>	3.20 <b>171.13</b>	4.56 <b>243.51</b>
47	8 6	56.75	1.42 <b>80.59</b>	1.60 <b>90.69</b>	1.82 <b>103.00</b>	2.04 <b>115.94</b>	2.30 <b>130.24</b>	2.65 <b>150.44</b>	3.27 <b>185.29</b>	4.65 <b>263.60</b>
48	8 9	60.13	1.45 <b>87.19</b>	1.63 <b>98.07</b>	1.85 <b>111.36</b>	2.08 <b>125.25</b>	2.34 <b>140.71</b>	2.70 <b>162.47</b>	3.33 <b>200.05</b>	4.73 <b>234.54</b>
49	9	63.62	1.48 <b>94.16</b>	1.66 <b>105.86</b>	1.89 <b>120.24</b>	2.12 <b>135.13</b>	2.39 <b>151.73</b>	2.75 <b>175.21</b>	3.39 <b>215.61</b>	4.82 <b>306.65</b>
50	9 3	67.20	1.51 <b>101.41</b>	1.70 <b>113.97</b>	1.93 <b>129.49</b>	2.16 <b>145.42</b>	2.43 <b>163.23</b>	2.81 <b>188.50</b>	3.45 <b>231.91</b>	4.91 <b>329.62</b>
51	9 6	70.88	1.54 <b>109.01</b>	1.73 <b>122.48</b>	1.96 <b>139.07</b>	2.20 <b>156.15</b>	2.47 <b>175.22</b>	2.85 <b>202.29</b>	3.51 <b>248.79</b>	4.99 <b>353.48</b>
52	9 9	74.66	1.57 <b>116.99</b>	1.76 <b>131.33</b>	2.00 <b>149.17</b>	2.24 <b>167.39</b>	2.52 <b>187.77</b>	2.90 <b>216.81</b>	3.57 <b>266.46</b>	5.07 <b>378.45</b>
53	10	78.54	1.60 <b>125.35</b>	1.79 <b>140.67</b>	2.03 <b>159.75</b>	2.28 <b>179.15</b>	2.56 <b>200.91</b>	2.95 <b>232.01</b>	3.63 <b>285.02</b>	5.15 <b>404.64</b>
54	10 6	86.59	1.65 <b>143.05</b>	1.85 <b>160.45</b>	2.11 <b>182.27</b>	2.36 <b>204.09</b>	2.64 <b>228.77</b>	3.05 <b>264.19</b>	3.75 <b>324.28</b>	5.31 <b>460.05</b>
55	11	95.03	1.71 <b>162.22</b>	1.91 <b>181.79</b>	2.17 <b>206.50</b>	2.43 <b>231.02</b>	2.72 <b>258.77</b>	3.15 <b>298.87</b>	3.86 <b>366.72</b>	5.47 <b>519.81</b>
56	11 6	103.9	1.58 <b>163.70</b>	1.76 <b>183.02</b>	1.98 <b>205.14</b>	2.2 <b>233.0</b>	2.5 <b>260.3</b>	2.8 <b>291.5</b>	3.2 <b>336.5</b>	4.0 <b>412.8</b>
57	12	113.1	1.62 <b>183.67</b>	1.82 <b>205.28</b>	2.03 <b>229.82</b>	2.3 <b>261.0</b>	2.6 <b>291.5</b>	2.9 <b>326.1</b>	3.3 <b>376.5</b>	4.1 <b>461.7</b>
58	12 6	122.7	1.67 <b>205.19</b>	1.87 <b>229.36</b>	2.09 <b>256.61</b>	2.4 <b>291.5</b>	2.6 <b>324.8</b>	3.0 <b>363.4</b>	3.4 <b>419.6</b>	4.2 <b>514.3</b>
59	13	132.7	1.72 <b>228.16</b>	1.92 <b>254.97</b>	2.15 <b>285.10</b>	2.4 <b>323.9</b>	2.7 <b>360.6</b>	3.0 <b>403.1</b>	3.5 <b>465.5</b>	4.3 <b>570.5</b>
60	14	153.9	1.81 <b>278.32</b>	2.02 <b>311.27</b>	2.26 <b>347.60</b>	2.6 <b>394.9</b>	2.9 <b>439.0</b>	3.2 <b>490.5</b>	3.7 <b>566.3</b>	4.5 <b>693.0</b>
61	15	176.7	1.90 <b>334.88</b>	2.12 <b>374.47</b>	2.37 <b>417.94</b>	2.7 <b>474.7</b>	3.0 <b>527.2</b>	3.3 <b>588.3</b>	3.8 <b>679.3</b>	4.7 <b>830.6</b>
62	16	201.1	1.98 <b>398.50</b>	2.22 <b>445.55</b>	2.47 <b>496.82</b>	2.8 <b>564.4</b>	3.1 <b>625.7</b>	3.5 <b>697.7</b>	4.0 <b>805.6</b>	4.9 <b>984.8</b>
63	17	227.0	2.07 <b>468.94</b>	2.31 <b>524.10</b>	2.57 <b>584.25</b>	2.9 <b>663.5</b>	3.2 <b>734.3</b>	3.6 <b>818.5</b>	4.2 <b>945.1</b>	5.1 <b>1153.7</b>
64	18	254.5	2.15 <b>546.60</b>	2.40 <b>611.24</b>	2.67 <b>680.45</b>	3.0 <b>773.1</b>	3.4 <b>854.0</b>	3.7 <b>951.5</b>	4.3 <b>1098.8</b>	5.3 <b>1340.5</b>
65	19	283.5	2.23 <b>631.99</b>	2.49 <b>706.56</b>	2.77 <b>785.95</b>	3.1 <b>892.8</b>	3.5 <b>985.8</b>	3.9 <b>1097.5</b>	4.5 <b>1267.4</b>	5.5 <b>1545.5</b>
66	20	314.2	2.31 <b>724.77</b>	2.58 <b>810.22</b>	2.87 <b>900.38</b>	3.3 <b>1022.6</b>	3.6 <b>1128.1</b>	4.0 <b>1255.4</b>	4.6 <b>1449.5</b>	5.6 <b>1766.8</b>

TABLE V.—CIRCULAR PIPES RUNNING FULL

## Kutter's Formula

When  $n$  equals .015.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Diam		Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
	ft. in.	sq.ft.	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)	.22361 (264)	.31623 (528)	.44721 (1056)
1	5	.136	.549 .075	.776 .106	1.228 0.167	1.736 0.237	2.455 0.335	3.88 0.53	5.49 0.75	7.76 1.06
2	6	.196	.639 .125	.904 .178	1.429 0.281	2.021 0.397	2.858 0.561	4.52 0.89	6.39 1.26	9.04 1.78
3	7	.267	.726 .194	1.026 0.274	1.623 0.434	2.295 0.613	3.246 0.868	5.13 1.37	7.26 1.94	10.26 2.74
4	8	.349	.809 .262	1.144 0.399	1.809 0.622	2.558 0.893	3.618 1.263	5.72 2.00	8.09 2.82	11.44 3.99
5	9	.442	.889 .393	1.257 0.555	1.987 0.878	2.810 1.241	3.974 1.756	6.28 2.78	8.89 3.93	12.57 5.55
6	10	.545	.965 .526	1.365 0.744	2.158 1.177	3.052 1.665	4.316 2.354	6.82 3.72	9.65 5.26	13.65 7.44
7	11	.660	1.045 0.690	1.477 0.975	2.336 1.542	3.303 2.180	4.671 3.083	7.39 4.88	10.45 6.89	14.77 9.75
8	1	.785	1.119 0.879	1.583 1.243	2.503 1.966	3.540 2.780	5.006 3.932	7.92 6.22	11.19 8.79	15.83 12.43
9	1	1	1.189 1.096	1.682 1.550	2.659 2.451	3.760 3.466	5.317 4.901	8.41 7.75	11.89 10.96	16.82 15.50
10	1	2	1.260 1.347	1.782 1.905	2.818 3.012	3.985 4.260	5.636 6.025	8.91 9.53	12.60 13.47	17.82 19.05
11	1	3	1.330 1.632	1.881 2.308	2.973 3.648	4.205 5.160	5.947 7.298	9.40 11.54	13.30 16.32	18.81 23.08
12	1	4	.657 .917	.96 1.35	1.40 1.95	1.98 2.76	3.12 4.36	4.42 6.17	6.25 8.72	9.88 13.79
13	1	6	.722 1.276	1.06 1.87	1.53 2.70	2.16 3.82	3.42 6.05	4.84 8.55	6.84 12.09	10.82 19.12
14	1	8	.784 1.711	1.15 2.50	1.66 3.62	2.35 5.12	3.71 8.09	5.25 11.45	7.42 16.19	11.73 25.59
15	1	10	.844 2.228	1.23 3.25	1.78 4.70	2.52 6.65	3.98 10.51	5.63 14.86	7.96 21.02	12.59 33.23
16	2	3.142	.902 2.834	1.32 4.13	1.90 5.97	2.69 8.44	4.25 13.35	6.01 18.88	8.50 26.70	13.43 42.21
17	2	2	.960 3.540	1.40 5.15	2.02 7.43	2.85 10.51	4.51 16.61	6.37 23.49	9.01 33.22	14.25 52.53
18	2	4	1.016 4.344	1.48 6.32	2.13 9.10	3.01 12.88	4.76 20.35	6.73 28.79	9.52 40.71	15.05 64.37
19	2	6	1.070 5.253	1.56 7.63	2.24 10.98	3.16 15.53	5.00 24.56	7.07 34.73	10.00 49.11	15.82 77.65
20	2	8	1.126 6.289	1.63 9.13	2.35 13.12	3.32 18.55	5.25 29.33	7.43 41.49	10.51 58.67	16.61 92.77
21	2	10	1.178 7.427	1.71 10.77	2.45 15.47	3.47 21.87	5.48 34.58	7.76 48.90	10.97 69.16	17.34 109.85
22	3	7.068	1.229 8.687	1.78 12.58	2.55 18.05	3.61 25.53	5.71 40.37	8.08 57.09	11.42 80.74	18.06 127.66

TABLE V.—CIRCULAR PIPES RUNNING FULL (Con.)

## Kutter's Formula

When  $n$  equals .015.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Diam		Area	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
	ft. in.	sq.ft.		.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)
23	3 2	7.88		.89 6.99	1.02 8.06	1.28 10.08	1.85 14.59	2.66 20.92	3.76 29.59	5.94 46.79	8.40 66.17
24	3 4	8.73		.92 8.05	1.07 9.29	1.33 11.61	1.92 16.77	2.76 24.05	3.90 34.01	6.16 53.77	8.71 76.04
25	3 6	9.62		.96 9.19	1.10 10.61	1.38 13.25	1.99 19.13	2.85 27.42	4.03 38.77	6.37 61.31	9.01 86.70
26	3 8	10.56		.99 10.44	1.14 12.06	1.42 15.04	2.06 21.70	2.94 31.09	4.16 43.97	6.58 69.52	9.31 98.32
27	3 10	11.54		1.02 11.81	1.18 13.64	1.47 17.00	2.12 24.50	3.04 35.10	4.30 49.63	6.80 78.47	9.62 110.98
28	4	12.57		1.06 13.28	1.22 15.33	1.52 19.09	2.19 27.51	3.13 39.38	4.43 55.69	7.01 88.05	9.91 124.53
29	4 2	13.64		1.09 14.85	1.26 17.15	1.57 21.35	2.25 30.73	3.23 43.99	4.56 62.30	7.21 98.34	10.20 139.08
30	4 4	14.75		1.12 16.53	1.29 19.08	1.61 23.74	2.32 34.16	3.31 48.86	4.69 69.11	7.41 109.27	10.48 154.53
31	4 6	15.90		1.15 18.34	1.33 21.17	1.66 26.32	2.38 37.84	3.40 54.12	4.81 76.53	7.61 121.00	10.76 171.13
32	4 9	17.72		1.20 21.23	1.38 24.53	1.72 30.46	2.47 43.74	3.53 62.54	4.99 88.45	7.89 139.84	11.16 197.77
33	5	19.64		1.25 24.45	1.44 28.24	1.79 35.05	2.56 50.29	3.66 71.84	5.18 101.61	8.18 160.65	11.57 227.20
34	5 3	21.65		1.00 21.65	1.14 24.70	1.29 27.93	1.49 32.26	1.85 40.01	2.65 57.37	3.78 81.92	5.35 115.84
35	5 6	23.76		1.04 24.61	1.18 28.06	1.33 31.69	1.54 36.61	1.91 45.38	2.74 65.03	3.91 92.80	5.52 131.24
36	5 9	25.97		1.07 27.84	1.22 31.68	1.38 35.76	1.59 41.31	1.97 51.18	2.82 73.28	4.03 104.54	5.69 147.83
37	6	28.27		1.11 31.30	1.26 35.60	1.42 40.18	1.64 46.37	2.03 57.42	2.91 82.16	4.14 117.14	5.86 165.66
38	6 3	30.68		1.14 35.04	1.30 39.76	1.46 44.85	1.69 51.82	2.09 64.09	2.99 91.67	4.26 130.61	6.02 184.72
39	6 6	33.18		1.18 39.02	1.33 44.27	1.51 49.94	1.74 57.67	2.15 71.28	3.07 101.91	4.37 145.11	6.18 205.20
40	6 9	35.79		1.21 43.30	1.37 49.06	1.55 55.32	1.79 63.88	2.21 78.91	3.15 112.76	4.48 160.46	6.34 226.95
41	7	38.49		1.24 47.88	1.41 54.15	1.59 61.04	1.83 70.51	2.26 87.02	3.23 124.27	4.60 176.84	6.50 250.08
42	7 3	41.28		1.28 52.68	1.44 59.53	1.63 67.08	1.88 77.45	2.32 95.61	3.30 136.40	4.70 194.07	6.65 274.44
43	7 6	44.18		1.31 57.79	1.48 65.30	1.66 73.51	1.92 84.87	2.37 104.75	3.38 149.37	4.81 212.41	6.80 300.42
44	7 9	47.17		1.34 63.26	1.51 71.42	1.70 80.34	1.97 92.79	2.43 114.49	3.46 168.08	4.94 231.90	6.95 327.95

TABLE V.—CIRCULAR PIPES RUNNING FULL (Con.)

## Kutter's Formula

When  $n$  equals .015.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



Z <sup>o</sup>	Diam ft. in.	Area sq.ft.	Square Root of Sine of Angle of Inclination. Figures in Parenthesis. Fall in Feet per Mile.							
			.00791 (.33)	.00898 (.426)	.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)
45	8	50.27	1.21 60.78	1.37 69.02	1.55 77.82	1.74 87.52	2.01 101.04	2.48 124.62	3.53 177.50	5.02 252.31
46	8	3 53.46	1.24 66.08	1.40 75.06	1.58 84.57	1.78 95.11	2.05 109.81	2.53 135.36	3.61 192.72	5.12 273.88
47	8	6 56.75	1.26 71.73	1.44 81.49	1.62 91.71	1.82 103.12	2.10 119.06	2.59 146.70	3.68 203.84	5.23 296.58
48	8	9 60.13	1.29 77.63	1.47 88.21	1.65 99.22	1.85 111.42	2.14 128.68	2.64 158.50	3.75 225.61	5.33 320.25
49	9	63.62	1.32 83.92	1.50 95.30	1.68 107.07	1.89 120.24	2.18 138.82	2.69 170.95	3.82 243.28	5.43 345.27
50	9	3 67.20	1.35 90.45	1.53 102.68	1.72 115.32	1.93 129.43	2.23 149.52	2.74 183.99	3.89 261.68	5.53 371.28
51	9	6 70.88	1.37 97.18	1.56 110.36	1.75 123.90	1.96 139.00	2.27 160.54	2.79 197.54	3.96 280.76	5.62 398.28
52	9	9 74.66	1.40 104.30	1.59 118.49	1.78 132.90	2.00 149.10	2.31 172.17	2.84 211.74	4.03 300.73	5.71 426.53
53	10	78.54	1.42 111.76	1.62 127.00	1.81 142.31	2.03 159.59	2.35 184.33	2.89 226.59	4.10 321.70	5.81 456.24
54	10	6 86.59	1.47 127.63	1.68 145.04	1.88 162.36	2.10 181.93	2.43 210.07	2.98 258.13	4.23 366.19	5.99 519.02
55	11	95.03	1.52 144.83	1.73 164.59	1.94 183.98	2.17 206.12	2.51 238.05	3.08 292.22	4.36 414.24	6.17 586.72
	ft. in.	sq.ft.	.00707 (.264)	.00791 (.33)	.00898 (.426)	.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)
56	11	6 103.9	1.41 145.94	1.58 163.60	1.79 185.82	2.00 207.53	2.2 232.4	2.6 268.4	3.2 329.3	4.5 466.5
57	12	113.1	1.45 163.88	1.62 183.56	1.84 208.44	2.06 232.53	2.3 260.4	2.7 300.6	3.3 368.6	4.6 521.8
58	12	6 122.7	1.49 183.22	1.67 204.94	1.90 232.80	2.12 259.55	2.4 290.5	2.7 335.4	3.3 411.0	4.7 581.6
59	13	132.7	1.54 203.87	1.72 227.90	1.95 258.96	2.17 288.29	2.4 322.5	2.8 372.4	3.4 456.2	4.9 645.1
60	14	153.9	1.62 249.38	1.81 278.48	2.06 316.35	2.29 351.91	2.6 393.0	2.9 453.8	3.6 555.6	5.1 784.8
61	15	176.7	1.70 300.78	1.90 335.42	2.16 381.01	2.39 423.07	2.7 472.2	3.1 545.4	3.8 666.9	5.3 941.0
62	16	201.1	1.78 358.49	1.99 399.71	2.26 453.99	2.50 502.65	2.8 561.2	3.2 647.8	3.9 791.6	5.6 1115.9
63	17	227.0	1.86 422.18	2.07 470.30	2.35 534.31	2.60 590.83	2.9 658.7	3.4 760.6	4.1 928.6	5.8 1308.3
64	18	254.5	1.94 492.91	2.16 548.64	2.45 623.20	2.71 688.34	3.0 766.7	3.5 885.6	4.2 1080.0	6.0 1521.0
65	19	283.5	2.01 570.75	2.24 634.54	2.54 720.73	2.81 795.59	3.1 885.5	3.6 1022.4	4.4 1246.7	6.2 1753.9
66	20	314.2	2.09 655.34	2.32 727.91	2.63 826.56	2.90 911.38	3.2 1014.1	3.7 1170.9	4.5 1426.6	6.4 2005.9

TABLE VI.—CIRCULAR PIPES RUNNING FULL

## Kutter's Formula

When  $n$  equals .020.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Diam		Area sq.ft.	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
	ft. in.			.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)	.22361 (264)	.31623 (528)	.44721 (1056)
1	5	.136	.368 .060 .430	.520 .071 .609	.822 .112 .962	1.163 0.159 1.361	1.645 0.224 1.925	2.601 0.355 3.043	3.68 0.50 4.30	5.20 0.71 6.09	
2	6	.196	.084 .490 .131	.120 .693 .185	.189 1.096 0.293	0.267 1.550 0.414	0.378 2.192 0.586	0.598 3.466 0.926	0.85 4.90 1.31	1.20 6.93 1.85	
3	7	.267	.548 .191 .604	.775 .271 .854	1.225 0.428 1.351	1.733 0.605 1.910	2.451 0.856 2.701	3.875 1.353 4.271	5.48 1.91 6.04	7.75 2.71 8.54	
4	8	.349	.267 .604 .191	.377 .854 .271	0.597 1.351 1.351	0.844 1.910 2.701	1.193 2.701 4.271	1.887 4.271 6.04	2.67 6.04 8.54	3.77 8.54 10.67	
5	9	.442	.658 .359 .715	.931 .508 1.011	1.472 0.803 1.599	2.082 1.136 2.261	2.944 1.606 3.198	4.655 2.539 5.056	6.58 3.59 7.15	9.31 5.08 10.11	
6	10	.545	.472 .768 .603	0.667 1.087 0.854	1.055 1.718 1.849	1.492 2.430 1.909	2.111 3.437 2.699	3.337 5.434 4.268	4.72 7.68 6.04	6.67 10.87 8.54	
7	11	.660	.818 .754 .870	1.157 1.067 1.230	1.830 1.687 1.945	2.588 3.386 2.750	3.660 5.374 3.889	5.787 8.334 6.149	8.18 7.54 8.70	11.57 10.67 12.30	
8	1	.785	.930 .920 1.129	1.315 1.300 1.595	2.079 2.056 2.523	2.940 2.908 3.569	4.157 4.113 5.047	6.573 6.502 7.979	9.30 9.20 11.29	13.15 13.01 15.96	
9	1	1	.922	.818 .754 .870	1.157 1.067 1.230	1.830 1.687 1.945	2.588 3.386 2.750	3.660 5.374 3.889	5.787 8.334 6.149	8.18 7.54 8.70	
10	1	2	1.069	.930 .920 1.129	1.315 1.300 1.595	2.079 2.056 2.523	2.940 2.908 3.569	4.157 4.113 5.047	6.573 6.502 7.979	9.30 9.20 11.29	
11	1	3	1.227	.920 .930 1.129	1.300 1.315 1.595	2.056 2.079 2.523	2.908 2.940 3.569	4.113 4.157 5.047	6.502 6.573 7.979	9.20 9.30 11.29	
12	1	4	1.396	.920 .930 1.129	1.300 1.315 1.595	2.056 2.079 2.523	2.908 2.940 3.569	4.113 4.157 5.047	6.502 6.573 7.979	9.20 9.30 11.29	
13	1	6	1.767	.920 .930 1.129	1.300 1.315 1.595	2.056 2.079 2.523	2.908 2.940 3.569	4.113 4.157 5.047	6.502 6.573 7.979	9.20 9.30 11.29	
14	1	8	2.182	.920 .930 1.129	1.300 1.315 1.595	2.056 2.079 2.523	2.908 2.940 3.569	4.113 4.157 5.047	6.502 6.573 7.979	9.20 9.30 11.29	
15	1	10	2.640	.920 .930 1.129	1.300 1.315 1.595	2.056 2.079 2.523	2.908 2.940 3.569	4.113 4.157 5.047	6.502 6.573 7.979	9.20 9.30 11.29	
16	2	3.142	.634 1.992 2.906	.925 2.906 4.20	1.34 4.20 5.94	1.89 5.94 9.40	2.99 9.40 13.29	4.23 13.29 18.79	5.98 18.79 29.71	9.46 29.71 44.72	
17	2	2	3.687	.676 2.492 3.632	.985 3.632 5.24	1.42 5.24 7.42	2.01 7.42 11.73	3.18 11.73 16.58	4.50 16.58 23.45	6.36 23.45 37.08	
18	2	4	4.276	.718 3.070 4.464	1.044 4.464 6.44	1.51 6.44 9.11	2.13 9.11 14.41	3.37 14.41 20.38	4.77 20.38 28.82	6.74 28.82 45.57	
19	2	6	4.909	.757 3.716 5.405	1.101 5.405 7.79	1.59 7.79 11.02	2.25 11.02 17.43	3.55 17.43 24.64	5.02 24.64 34.85	7.10 34.85 55.10	
20	2	8	5.585	.799 4.462 6.479	1.160 6.479 9.33	1.67 9.33 13.20	2.36 13.20 20.87	3.74 20.87 29.51	5.28 29.51 41.74	7.47 41.74 65.99	
21	2	10	6.305	.838 5.284 7.661	1.215 7.661 11.03	1.75 11.03 15.59	2.47 15.59 24.65	3.91 24.65 34.87	5.53 34.87 49.31	7.82 49.31 77.96	
22	3	7.068	.875 6.185 8.969	1.269 8.969 12.90	1.83 12.90 18.24	2.58 18.24 28.85	4.08 28.85 40.79	5.77 40.79 57.68	8.16 57.68 91.21	12.90 91.21 139.0	

TABLE VI.—CIRCULAR PIPES RUNNING FULL (*Con.*)

## Kutter's Formula

When  $n$  equals .020.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Diam		Area	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.								
	ft.	in.		sq.ft.	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)
23	3	2	7.88	.63 4.99	.73 5.75	.91 7.20	1.32 10.42	1.90 14.98	2.69 21.18	4.25 33.50	6.02 47.38	
24	3	4	8.73	.66 5.75	.76 6.64	.95 8.30	1.38 12.01	1.98 17.24	2.80 24.39	4.42 38.56	6.25 54.54	
25	3	6	9.62	.68 6.58	.79 7.59	.99 9.49	1.43 13.72	2.05 19.69	2.90 27.85	4.58 44.04	6.47 62.28	
26	3	8	10.56	.71 7.49	.82 8.65	1.02 10.79	1.48 15.60	2.12 22.36	3.00 31.64	4.74 50.02	6.70 70.74	
27	3	10	11.54	.74 8.48	.85 9.80	1.06 12.22	1.53 17.65	2.19 25.29	3.10 35.75	4.90 56.54	6.93 79.96	
28	4		12.57	.76 9.55	.88 11.03	1.09 13.75	1.58 19.84	2.26 28.41	3.20 40.19	5.06 63.53	7.15 89.85	
29	4	2	13.64	.79 10.70	.91 12.35	1.13 15.39	1.63 22.18	2.33 31.77	3.30 44.93	5.21 71.05	7.37 100.48	
30	4	4	14.75	.81 11.93	.93 13.78	1.16 17.15	1.67 24.69	2.40 35.35	3.39 50.00	5.36 79.05	7.58 111.79	
31	4	6	15.90	.83 13.25	.96 15.30	1.20 19.04	1.72 27.37	2.46 39.19	3.49 55.43	5.51 87.63	7.79 123.94	
32	4	9	17.72	.87 15.36	1.00 17.74	1.25 22.06	1.79 31.69	2.56 45.37	3.62 64.17	5.73 101.45	8.10 143.47	
33	5		19.64	.90 17.71	1.04 20.46	1.30 25.43	1.86 36.50	2.66 52.21	3.76 73.85	5.95 116.77	8.41 165.13	
	ft.	in.	sq.ft.	.00898 (.426)	.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	
34	5	3	21.65	.73 15.72	.83 17.93	.94 20.28	1.08 23.42	1.34 29.07	1.93 41.74	2.76 59.64	3.90 84.86	
35	5	6	23.76	.75 17.91	.86 20.38	.97 23.07	1.12 26.63	1.39 33.02	2.00 47.40	2.85 67.71	4.03 95.75	
36	5	9	25.97	.78 20.28	.89 23.06	1.00 26.07	1.16 30.10	1.44 37.29	2.06 53.52	2.94 76.37	4.16 108.02	
37	6		28.27	.81 22.85	.92 25.96	1.04 29.29	1.20 33.84	1.48 41.93	2.13 60.08	3.03 85.70	4.29 121.21	
38	6	3	30.68	.83 25.59	.95 29.02	1.07 32.77	1.23 37.86	1.53 46.88	2.19 67.10	3.12 95.69	4.41 135.33	
39	6	6	33.18	.86 28.54	.98 32.35	1.10 36.53	1.27 42.18	1.57 52.20	2.25 74.66	3.21 106.45	4.54 150.52	
40	6	9	35.79	.89 31.71	1.00 35.93	1.13 40.51	1.31 46.81	1.62 57.90	2.31 82.70	3.29 117.88	4.66 166.69	
41	7		38.49	.91 35.10	1.03 39.72	1.16 44.76	1.34 51.69	1.66 63.92	2.37 91.29	3.38 130.00	4.78 183.88	
42	7	3	41.28	.94 38.64	1.06 43.72	1.19 49.25	1.38 56.89	1.70 70.26	2.43 100.32	3.46 142.88	4.89 202.03	
43	7	6	44.18	.96 42.46	1.09 48.02	1.22 54.03	1.41 62.43	1.74 77.05	2.49 109.96	3.54 156.57	5.01 221.38	
44	7	9	47.17	.99 46.56	1.11 52.55	1.25 59.16	1.45 68.31	1.79 84.30	2.55 120.24	3.63 171.10	5.13 242.00	

TABLE VI.—CIRCULAR PIPES RUNNING FULL (*Con.*)

## Kutter's Formula

When  $n$  equals .020.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.

No.	Diam. ft. in.	Area sq.ft.	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.							
			.00791 (.33)	.00898 (.426)	.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)
45	8	50.27	.89 44.74	1.01 50.82	1.14 57.36	1.28 64.50	1.48 74.50	1.83 91.89	2.61 131.00	3.71 186.35
46	8 3	53.46	.91 48.70	1.04 55.33	1.17 62.44	1.31 70.19	1.52 81.05	1.87 99.92	2.66 142.36	2.79 202.45
47	8 6	56.75	.93 52.95	1.06 60.16	1.20 67.82	1.34 76.22	1.55 87.96	1.91 108.39	2.72 154.36	3.87 219.45
48	8 9	60.13	.95 57.36	1.08 65.12	1.22 73.36	1.37 82.44	1.58 95.25	1.95 117.25	2.78 166.86	3.95 237.21
49	9	63.62	.98 62.03	1.11 70.43	1.25 79.33	1.40 89.07	1.62 102.87	1.99 126.60	2.83 180.11	4.02 255.83
50	9 3	67.20	1.00 66.93	1.13 76.00	1.27 85.48	1.43 95.96	1.65 110.88	2.03 136.35	2.89 193.94	4.10 275.45
51	9 6	70.88	1.02 72.01	1.15 81.80	1.30 91.86	1.46 103.20	1.68 119.15	2.07 146.51	2.94 208.32	4.17 295.71
52	9 9	74.66	1.04 77.35	1.18 87.88	1.32 98.63	1.48 110.72	1.71 127.82	2.11 157.16	2.99 223.46	4.25 317.01
53	10	78.54	1.06 83.02	1.20 94.25	1.35 105.72	1.51 118.60	1.74 136.97	2.14 168.39	3.05 239.31	4.32 339.27
54	10 6	86.59	1.10 94.99	1.25 107.89	1.40 120.79	1.56 135.43	1.81 156.38	2.22 192.14	3.15 272.55	4.47 386.62
55	11	95.03	1.14 107.95	1.29 122.59	1.44 137.03	1.62 153.66	1.87 177.42	2.29 217.90	3.25 309.04	4.61 437.71
56	11 6	103.9	1.05 108.96	1.18 122.15	1.34 138.77	1.49 154.87	1.67 173.57	1.93 200.37	2.4 246.0	3.4 348.3
57	12	113.1	1.08 122.49	1.21 137.19	1.38 155.85	1.54 173.84	1.72 194.65	1.99 224.73	2.4 275.6	3.5 390.2
58	12 6	122.7	1.12 137.08	1.25 153.52	1.42 174.39	1.58 194.39	1.77 217.46	2.05 251.09	2.5 307.7	3.5 435.3
59	13	132.7	1.15 152.77	1.29 170.96	1.46 194.18	1.63 216.22	1.82 241.70	2.10 279.13	2.6 341.9	3.6 483.5
60	14	153.9	1.22 187.50	1.36 209.51	1.55 237.99	1.72 264.32	1.92 295.41	2.22 340.98	2.7 417.3	3.8 559.3
61	15	176.7	1.28 226.56	1.43 252.89	1.63 287.17	1.80 318.63	2.01 355.74	2.32 410.70	2.8 502.1	4.0 708.3
62	16	201.1	1.35 270.63	1.50 301.79	1.70 342.61	1.89 379.60	2.11 423.43	2.43 488.98	3.0 596.9	4.2 841.6
63	17	227.0	1.41 319.59	1.57 355.91	1.78 404.25	1.97 447.15	2.19 497.99	2.53 575.17	3.1 702.3	4.4 988.7
64	18	254.5	1.47 373.82	1.64 416.06	1.86 472.55	2.05 521.92	2.28 580.96	2.64 670.78	3.2 818.6	4.5 1151.5
65	19	283.5	1.53 433.80	1.70 482.29	1.93 547.78	2.13 604.20	2.37 671.97	2.74 776.02	3.3 945.9	4.7 1330.9
66	20	314.2	1.59 498.89	1.76 554.18	2.00 629.58	2.21 693.35	2.45 770.95	2.83 890.33	3.5 1084.2	4.9 1524.0

TABLE VII.—SUPPLEMENTAL

Giving diam. in ft. and ins., area in sq.ft., hydraulic radius  $r$ , and its square root, for 150 graduated circular conduits.

\* Found in the Kutter flowage tables.

† Found in the D'Arcy flowage tables.



No.	Diameter.			Area sq.ft.	$r$ feet.	$\sqrt{r}$ feet.
	feet.	ins.	feet.			
1	$\frac{1}{8}$ in. diam. = .01041667 ft. = $R$ for $\frac{1}{8}$ in. diam.	$\frac{1}{8}$	.0208	.0003	.0052	.072
2		$\frac{1}{4}$	.0313	.0008	.0078	.088
3		$\frac{3}{8}$	.0417	.0014	.0104	.102
4		$\frac{1}{2}$	.0521	.0021	.0130	.114
5		$\frac{5}{8}$	.0625	.0031	.0156	.125
6†		1	.0833	.0055	.0208	.144
7†		$1\frac{1}{4}$	.1042	.0085	.0260	.161
8†		$1\frac{1}{2}$	.1250	.0123	.0312	.177
9†		$1\frac{3}{4}$	.1458	.0167	.0364	.191
10†		2	.1667	.0218	.0417	.204
11†		$2\frac{1}{2}$	.2083	.0341	.0251	.228
12†		3	.2500	.0491	.0625	.250
13		$3\frac{1}{2}$	.2917	.0668	.0729	.270
14†		4	.3333	.0873	.0833	.289
15		$4\frac{1}{2}$	.3750	.1104	.0938	.306
16*†		5	.4167	.1363	.1042	.325
17		$5\frac{1}{2}$	.4583	.1650	.1146	.339
18*†		6	.5000	.1964	.1250	.354
19		$6\frac{1}{2}$	.5417	.2305	.1354	.368
20*†		7	.5833	.2673	.1458	.382
21		$7\frac{1}{2}$	.6250	.3068	.1563	.395
22*†		8	.6667	.3491	.1667	.408
23		$8\frac{1}{2}$	.7083	.3940	.1771	.421
24*†		9	.7500	.4418	.1875	.433
25		$9\frac{1}{2}$	.7917	.4923	.1979	.445
26*†		10	.8333	.5454	.2083	.456
27		$10\frac{1}{2}$	.8750	.6013	.2188	.468
28*		11	.9167	.6600	.2292	.479
29		$11\frac{1}{2}$	.9583	.7213	.2396	.489
30*†		12	1.0000	.7854	.2500	.500
31*	1	1	1.083	.9218	.271	.520
32*†		2	1.167	1.069	.292	.540
33*		3	1.250	1.227	.313	.559
34*†		4	1.333	1.396	.333	.577
35		5	1.417	1.576	.354	.595
36*†		6	1.500	1.767	.375	.612
37		7	1.583	1.969	.396	.629
38*†		8	1.667	2.182	.417	.646
39		9	1.750	2.405	.437	.661
40*†		10	1.833	2.640	.458	.677
41	2	11	1.917	2.885	.479	.692
42*†		12	2.000	3.142	.500	.707
43		1	2.083	3.409	.521	.722
44*		2	2.166	3.687	.542	.736
45†		3	2.250	3.976	.562	.750
46*		4	2.333	4.276	.583	.764
47		5	2.416	4.587	.604	.777
48*†		6	2.500	4.909	.625	.790
49		7	2.584	5.241	.646	.804
50*		8	2.667	5.585	.667	.817

TABLE VII.—SUPPLEMENTAL (*Con.*)

Giving diam. in ft. and ins., area in sq.ft., hydraulic radius  $r$ , and its square root, for 150 graduated circular conduits.

\* Found in the Kutter flowage tables.

† Found in the D'Arcy flowage tables



No.	Diameter.			Area sq.ft.	$r$ feet.	$\sqrt{r}$ feet.
	feet.	ins.	feet.			
51†		9	2.750	5.939	.687	.829
52*		10	2.834	6.305	.708	.842
53		11	2.916	6.681	.729	.854
54*†	3		3.000	7.068	.750	.866
55		1	3.083	7.466	.771	.878
56*		2	3.167	7.875	.792	.890
57		3	3.250	8.295	.812	.901
58*†		4	3.333	8.726	.833	.913
59		5	3.417	9.169	.854	.924
60*		6	3.500	9.621	.875	.935
61		7	3.583	10.084	.896	.946
62*†		8	3.667	10.559	.917	.957
63		9	3.750	11.044	.937	.968
64*		10	3.833	11.541	.958	.979
65		11	3.917	12.048	.979	.990
66*†	4		4.000	12.566	1.000	1.000
67		1	4.083	13.096	1.021	1.010
68*		2	4.167	13.635	1.042	1.021
69		3	4.250	14.186	1.062	1.031
70*		4	4.333	14.748	1.083	1.041
71		5	4.417	15.321	1.104	1.051
72*†		6	4.500	15.904	1.125	1.061
73		7	4.583	16.499	1.146	1.070
74		8	4.667	17.104	1.167	1.080
75*		9	4.750	17.721	1.187	1.089
76		10	4.833	18.348	1.208	1.099
77		11	4.917	18.986	1.229	1.109
78*†	5		5.000	19.635	1.250	1.118
79		1	5.083	20.292	1.271	1.127
80		2	5.167	20.969	1.292	1.137
81*		3	5.250	21.641	1.313	1.146
82		4	5.333	22.337	1.333	1.155
83		5	5.417	23.047	1.354	1.164
84*		6	5.500	23.758	1.375	1.173
85		7	5.583	24.481	1.396	1.181
86		8	5.667	25.222	1.417	1.190
87*		9	5.750	25.967	1.438	1.199
88		10	5.833	26.722	1.458	1.208
89		11	5.917	27.498	1.479	1.216
90*†	6		6.000	28.274	1.500	1.225
91		1	6.083	29.062	1.521	1.233
92		2	6.167	29.870	1.542	1.242
93*		3	6.250	30.680	1.563	1.250
94		4	6.333	31.500	1.583	1.258
95		5	6.417	32.341	1.604	1.267
96*		6	6.500	33.183	1.625	1.275
97		7	6.583	34.036	1.646	1.283
98		8	6.667	34.910	1.667	1.291
99*		9	6.750	35.785	1.688	1.299
100		10	6.833	36.670	1.708	1.307

TABLE VII.—SUPPLEMENTAL (Con.)

Giving diam. in ft. and ins., area in sq.ft., hydraulic radius  $r$ , and its square root, for 150 graduated circular conduits.

\* Found in the Kutter flowage tables.

† Found in the D'Arcy flowage tables.



No.	Diameter.			Area sq.ft.	$r$ feet.	$\sqrt{r}$ feet.
	feet.	ins.	feet.			
101	6	11	6.92	37.58	1.729	1.315
102*†	7		7.00	38.49	1.750	1.323
103*		3	7.25	41.28	1.812	1.346
104*		6	7.50	44.18	1.879	1.369
105*		9	7.75	47.17	1.937	1.392
106*†	8		8.00	50.27	2.000	1.414
107*		3	8.25	53.46	2.062	1.436
108*		6	8.50	56.75	2.125	1.458
109*		9	8.75	60.13	2.187	1.479
110*†	9		9.00	63.62	2.250	1.500
111*		3	9.25	67.20	2.312	1.521
112*		6	9.50	70.88	2.375	1.541
113*		9	9.75	74.66	2.437	1.561
114*†	10		10.00	78.54	2.500	1.581
115		3	10.25	82.52	2.562	1.601
116*		6	10.50	86.59	2.625	1.620
117		9	10.75	90.76	2.687	1.639
118*	11		11.00	95.03	2.750	1.658
119		3	11.25	99.40	2.812	1.677
120*		6	11.50	103.87	2.875	1.696
121		9	11.75	108.43	2.937	1.714
122*†	12		12.00	113.10	3.000	1.732
123		3	12.25	117.86	3.063	1.750
124*		6	12.50	122.72	3.125	1.768
125		9	12.75	127.68	3.188	1.785
126*	13		13.00	132.73	3.250	1.803
127		3	13.25	137.89	3.313	1.820
128		6	13.50	143.14	3.375	1.837
129		9	13.75	148.49	3.438	1.854
130*†	14		14.00	153.94	3.500	1.871
131		3	14.25	159.49	3.563	1.887
132		6	14.50	165.13	3.625	1.904
133		9	14.75	170.87	3.688	1.920
134*	15		15.00	176.72	3.750	1.936
135		6	15.50	188.69	3.875	1.968
136*†	16		16.00	201.06	4.000	2.000
137		6	16.50	213.83	4.125	2.031
138*	17		17.00	226.98	4.250	2.061
139		6	17.50	240.53	4.375	2.092
140*†	18		18.00	254.47	4.500	2.121
141		6	18.50	268.80	4.625	2.151
142*	19		19.00	283.53	4.750	2.180
143		6	19.50	298.65	4.875	2.208
144*†	20		20.00	314.16	5.000	2.236
145		6	20.50	330.06	5.125	2.264
146	21		21.00	346.36	5.250	2.291
147	22		22.00	380.13	5.500	2.345
148	23		23.00	415.48	5.750	2.398
149	24		24.00	452.39	6.000	2.449
150	25		25.00	490.88	6.250	2.500

TABLE VIII.—CIRCULAR PIPES RUNNING FULL

All pipes 6 ins. or more in diameter, Kutter's formula.

All pipes 3 ins. or less in diameter, D'Arcy's formula.

Coefficients between 3 and 6 ins. have been interpolated.



Quantity or Volume of Flow.	Diam.		Area sq. ft.	Mean Velocity Feet per Sec.	Grade or Fall in Feet per Mile when				No.
	ft.	ins.			n = .010	n = .012	n = .015	n = .020	
.0250 sec.-ft. or 1.0 inch	..	1½	.0085	2.94	244.0	333.0	532.0	931.0	1
	..	1½	.0123	2.03	89.6	123.0	198.0	387.0	2
	..	1½	.0167	1.50	39.6	55.0	87.5	175.0	3
	..	2	.0218	1.15	19.4	25.0	43.0	86.2	4
	..	2½	.0341	0.73	5.84	8.05	12.9	28.1	5
.0375 sec.-ft. or 1.5 inches	..	1½	.0123	3.05	202.0	278.0	447.0	873.0	6
	..	1½	.0167	2.25	89.1	124.0	197.0	393.0	7
	..	2	.0218	1.72	43.5	56.0	96.1	193.0	8
	..	2½	.0341	1.10	13.3	18.3	29.3	63.9	9
	..	3	.0491	0.76	5.03	7.62	11.1	25.2	10
.0500 sec.-ft. or 2.0 inches	..	1½	.0167	2.99	157.0	218.0	348.0	694.0	11
	..	2	.0218	2.29	77.0	99.3	170.0	342.0	12
	..	2½	.0341	1.47	23.7	32.6	52.4	114.0	13
	..	3	.0491	1.02	9.05	13.7	20.0	45.4	14
	..	3½	.0668	0.75	4.07	6.48	9.59	20.6	15
.0750 sec.-ft. or 3.0 inches	..	2	.0218	3.44	174.0	224.0	384.0	771.0	16
	..	2½	.0341	2.20	53.1	73.1	117.0	256.0	17
	..	3	.0491	1.53	20.4	30.9	45.1	102.0	18
	..	3½	.0668	1.12	9.09	14.5	21.4	46.0	19
	..	4	.0873	0.86	4.53	7.65	11.3	23.1	20
.125 sec.-ft. or 5.0 inches	..	2½	.0341	3.67	148.0	203.0	326.0	711.0	21
	..	3	.0491	2.55	56.6	85.8	125.0	284.0	22
	..	3½	.0668	1.87	25.3	40.3	59.6	128.0	23
	..	4	.0873	1.43	12.5	21.1	31.2	63.9	24
	..	5	.1363	0.92	4.79	7.97	11.6	22.8	25
.175 sec.-ft. or 7.0 inches	..	3	.0491	3.56	110.0	167.0	244.0	553.0	26
	..	3½	.0668	2.62	49.7	79.1	117.0	252.0	27
	..	4	.0873	2.00	24.5	41.3	61.1	125.0	28
	..	5	.1363	1.28	9.27	15.4	22.5	44.1	29
	..	6	.1964	0.89	3.37	5.55	10.2	18.6	30
.250 sec.-ft. or 10.0 inches	..	3½	.0668	3.74	101.0	161.0	238.0	513.0	31
	..	4	.0873	2.86	50.1	84.5	125.0	256.0	32
	..	5	.1363	1.83	19.0	31.5	46.0	90.2	33
	..	6	.1964	1.27	6.86	11.3	20.9	37.8	34
	..	7	.2673	0.94	2.96	4.84	8.86	19.4	35
.375 sec.-ft. or 15.0 inches	..	4	.0873	4.30	113.0	191.0	282.0	578.0	36
	..	5	.1363	2.75	42.6	71.1	104.0	204.0	37
	..	6	.1964	1.91	15.5	25.6	47.2	85.6	38
	..	7	.2673	1.40	6.56	10.7	19.6	43.1	39
	..	8	.3491	1.07	3.31	5.08	9.24	20.1	40
.50 sec.-ft. or 20 inches	..	5	.1363	3.67	76.2	127.0	185.0	363.0	41
	..	6	.1964	2.55	27.7	45.6	84.1	153.0	42
	..	7	.2673	1.87	11.7	19.2	35.1	76.9	43
	..	8	.3491	1.43	5.57	9.07	16.5	36.0	44
	..	10	.5454	0.92	1.74	2.82	4.80	10.3	45
.75 sec.-ft. or 30 inches	..	6	.1964	3.82	62.1	102.0	189.0	342.0	46
	..	7	.2673	2.81	26.4	43.2	79.1	173.0	47
	..	8	.3491	2.15	12.6	20.5	37.3	81.3	48
	..	10	.5454	1.38	3.72	6.00	10.8	23.2	49
	1	..	.7854	0.96	1.42	2.29	3.88	8.24	50

TABLE VIII.—CIRCULAR PIPES RUNNING FULL (Con.)

All pipes 6 ins. or more in diameter, Kutter's formula.

All pipes 3 ins. or less in diameter, D'Arcy's formula.

Coefficients between 3 and 6 ins. have been interpolated.



Quantity or Volume of Flow.	Diam.		Area sq.ft.	Mean Velocity Feet per Sec.	Grade or Fall in Feet per Mile when				No.
	ft.	ins.			n = .010	n = .012	n = .015	n = .020	
1.25 sec.-ft. or 50 inches	..	7	.267	4.68	73.3	120.0	220.0	481.0	51
	..	8	.349	3.58	34.9	56.8	103.0	225.0	52
	..	10	.545	2.29	10.3	16.5	29.7	63.9	53
	1	..	.785	1.59	3.93	5.97	10.7	22.6	54
	1	4	1.396	0.90	0.94	1.40	2.30	4.56	55
1.75 sec.-ft. or 70 inches	..	8	.349	5.01	68.4	111.0	203.0	441.0	56
	..	10	.545	3.21	20.2	32.4	58.4	126.0	57
	1	..	.785	2.23	7.35	11.7	21.0	44.5	58
	1	3	1.227	1.43	2.30	3.64	6.11	12.8	59
	1	6	1.767	0.99	0.95	1.42	2.32	4.56	60
2.50 sec.-ft. or 100 inches	..	9	.442	5.66	73.1	118.0	214.0	464.0	61
	1	..	.785	3.18	14.9	23.9	42.6	90.4	62
	1	3	1.227	2.04	4.47	7.06	12.4	26.0	63
	1	6	1.767	1.41	1.83	2.69	4.48	9.26	64
	1	8	2.182	1.15	1.04	1.63	2.66	5.20	65
3.75 sec.-ft. or 150 inches	..	10	.545	6.88	92.6	149.0	268.0	577.0	66
	1	2	1.069	3.51	14.6	23.2	41.0	86.0	67
	1	6	1.767	2.12	3.71	5.82	10.1	20.9	68
	1	10	2.640	1.42	1.38	2.03	3.51	6.83	69
	2	2	3.687	1.02	0.59	0.91	1.49	2.83	70
5.00 sec.-ft. or 200 inches	1	..	.785	6.37	60.0	95.8	171.0	363.0	71
	1	4	1.396	3.58	12.5	19.8	34.7	72.2	72
	1	8	2.182	2.29	3.72	5.81	10.1	20.6	73
	2	..	3.142	1.59	1.52	2.24	3.86	7.46	74
	2	6	4.909	1.02	0.48	0.74	1.20	2.26	75
7.50 sec.-ft. or 300 inches	1	4	1.396	5.37	28.2	44.5	78.0	162.0	76
	1	8	2.182	3.44	8.40	13.1	22.7	46.5	77
	2	..	3.142	2.39	3.26	4.87	8.36	16.9	78
	2	6	4.909	1.53	1.03	1.58	2.56	4.90	79
	3	..	7.068	1.06	0.40	0.61	0.98	1.94	80
12.5 sec.-ft. or 500 inches	1	6	1.767	7.07	41.3	64.8	113.0	233.0	81
	2	..	3.142	3.98	8.72	13.5	23.2	46.8	82
	2	6	4.909	2.55	2.72	4.05	6.86	13.6	83
	3	..	7.068	1.77	1.06	1.62	2.61	4.97	84
	3	6	9.621	1.30	0.50	0.73	1.18	2.19	85
17.5 sec.-ft. or 700 inches	2	..	3.142	5.57	17.1	26.4	45.4	91.6	86
	2	6	4.909	3.56	5.15	7.89	13.4	26.6	87
	3	..	7.068	2.48	2.00	3.05	4.98	9.75	88
	3	6	9.621	1.82	0.94	1.38	2.21	4.17	89
	4	..	12.566	1.39	0.47	0.68	1.10	2.05	90
25.0 sec.-ft. or 1000 inches	2	6	4.909	5.09	10.5	16.1	27.3	54.3	91
	3	..	7.068	3.54	3.98	6.04	10.1	19.9	92
	3	6	9.621	2.60	1.86	2.64	4.40	8.52	93
	4	..	12.566	1.99	0.93	1.36	2.18	4.09	94
	5	..	19.635	1.27	0.29	0.43	0.69	1.27	95
37.5 sec.-ft. or 1500 inches	3	..	7.068	5.31	8.95	13.6	22.8	44.7	96
	3	6	9.621	3.90	3.93	5.94	9.89	19.2	97
	4	..	12.566	2.98	1.96	2.95	4.77	9.17	98
	5	..	19.635	1.91	0.63	0.95	1.51	2.79	99
	6	..	28.274	1.33	0.25	0.38	0.59	1.06	100

TABLE VIII.—CIRCULAR PIPES RUNNING FULL (Con.)

All pipes 6 ins. or more in diameter, Kutter's formula.

All pipes 3 ins. or less in diameter, D'Arey's formula.

Coefficients between 3 and 6 ins. have been interpolated.



Quantity or Volume of Flow.	Diam.		Area sq.ft.	Mean Velocity Feet per Sec.	Grade or Fall in Feet per Mile when				No.
	ft.	ins.			$n = .010$	$n = .012$	$n = .015$	$n = .020$	
50 sec.-ft.	3	6	9.62	5.20	6.99	10.6	17.6	34.1	101
or	4	..	12.57	3.98	3.50	5.15	8.52	16.4	102
2000 inches	5	..	19.64	2.55	1.10	1.64	2.62	4.85	103
	6	..	28.27	1.77	0.45	0.63	1.02	1.88	104
	7	..	38.49	1.30	0.19	0.29	0.47	0.82	105
75 sec.-ft.	4	..	12.57	5.97	7.71	11.6	19.2	36.8	106
or	5	..	19.64	3.82	2.41	3.59	5.75	10.9	107
3000 inches	6	..	28.27	2.65	0.95	1.38	2.19	4.03	108
	7	..	38.49	1.95	0.44	0.62	1.00	1.82	109
	8	..	50.27	1.49	0.22	0.31	0.49	0.89	110
125 sec.-ft.	5	..	19.64	6.37	6.58	9.80	16.0	30.3	111
or	6	..	28.27	4.42	2.54	3.76	6.01	11.2	112
5000 inches	7	..	38.49	3.25	1.14	1.69	2.67	4.89	113
	8	..	50.27	2.49	0.58	0.84	1.33	2.41	114
	10	..	78.54	1.59	0.18	0.26	0.41	0.73	115
175 sec.-ft.	6	..	28.27	6.19	4.92	7.28	11.8	22.0	116
or	7	..	38.49	4.55	2.21	3.26	5.18	9.58	117
7000 inches	8	..	50.27	3.48	1.11	1.62	2.56	4.65	118
	10	..	78.54	2.23	0.35	0.50	0.79	1.43	119
	12	..	113.10	1.55	0.13	0.19	0.30	0.54	120
250 sec.-ft.	7	..	38.49	6.50	4.47	6.58	10.6	19.5	121
or	8	..	50.27	4.97	2.23	3.27	5.18	9.49	122
10,000 inches	10	..	78.54	3.18	0.70	1.01	1.61	2.88	123
	12	..	113.10	2.21	0.27	0.39	0.61	1.09	124
	14	..	153.94	1.62	0.12	0.17	0.26	0.47	125
375 sec.-ft.	8	..	50.27	7.46	5.03	7.37	11.7	21.4	126
or	10	..	78.54	4.77	1.57	2.26	3.58	6.44	127
15,000 inches	12	..	113.10	3.32	0.61	0.88	1.37	2.44	128
	14	..	153.94	2.44	0.27	0.39	0.60	1.07	129
	16	..	201.06	1.87	0.13	0.19	0.29	0.52	130
500 sec.-ft.	10	..	78.54	6.37	2.78	4.03	6.35	11.5	131
or	12	..	113.10	4.42	1.07	1.55	2.42	4.33	132
20,000 inches	14	..	153.94	3.25	0.48	0.69	1.07	1.90	133
	16	..	201.06	2.49	0.23	0.33	0.52	0.92	134
	18	..	254.47	1.96	0.12	0.17	0.27	0.48	135
750 sec.-ft.	12	..	113.10	6.63	2.41	3.47	5.44	9.73	136
or	14	..	153.94	4.87	1.08	1.55	2.41	4.27	137
30,000 inches	16	..	201.06	3.73	0.53	0.76	1.18	2.10	138
	18	..	254.47	2.95	0.28	0.40	0.63	1.11	139
	20	..	314.16	2.39	0.16	0.23	0.35	0.63	140



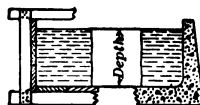
TABLE IX.—OPEN RECTANGULAR CHANNELS (Con.)

## Kutter's Formula

When  $n$  equals .011.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width feet	Depth feet	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.00791 (.33)	.00898 (.426)	.01000 (.528)	.01414 (1.06)	.02236 (2.64)	.03162 (5.28)
21	5.5	2.75	15.13	1.375	1.17	1.29 19.44	1.46 22.08	1.66 25.12	2.40 36.27	3.84 58.08	5.47 82.72
22	6.0	3.0	18.00	1.500	1.23	1.37 24.66	1.56 28.01	1.77 31.79	2.55 45.81	4.07 73.24	5.79 104.24
23	6.5	3.25	21.13	1.625	1.28	1.45 30.65	1.65 34.81	1.87 39.43	2.68 56.70	4.29 90.52	6.10 128.78
24	7.0	3.5	24.50	1.750	1.32	1.53 37.46	1.74 42.56	1.96 48.09	2.82 69.04	4.50 110.12	6.39 156.56
25	7.5	3.75	28.13	1.875	1.37	1.61 45.14	1.82 51.24	2.06 57.83	2.95 82.91	4.70 132.08	6.67 187.65
26	8.0	4.0	32.00	2.000	1.41	1.68 53.73	1.91 61.02	2.15 68.74	3.08 98.40	4.89 156.61	6.95 222.37
27	9.0	4.5	40.50	2.250	1.50	1.82 73.79	2.07 83.84	2.33 94.20	3.32 134.42	5.28 213.64	7.48 302.90
28	10.0	5.0	50.00	2.500	1.58	1.96 98.00	2.23 111.30	2.50 124.75	3.55 177.50	5.64 281.85	7.99 399.80
29	11.0	5.1	56.10	2.646	1.63	2.04 114.39	2.32 129.93	2.59 145.36	3.68 206.62	5.84 327.79	8.27 464.17
30	12.0	5.2	62.40	2.786	1.67	2.11 131.73	2.40 149.57	2.68 167.23	3.80 237.37	6.03 376.33	8.54 532.71
31	13	5.3	68.9	2.919	1.71	1.74 119.96	1.95 134.08	2.2 150.2	2.5 170.6	2.8 190.4	3.9 270.0
32	14	5.4	75.6	3.048	1.75	1.79 135.55	2.01 151.58	2.2 169.6	2.6 192.7	2.8 214.9	4.0 304.4
33	16	5.6	89.6	3.294	1.82	1.89 169.52	2.12 189.50	2.4 211.8	2.7 240.6	3.0 267.8	4.2 378.9
34	18	5.8	104.4	3.527	1.88	1.98 206.92	2.22 231.35	2.5 258.4	2.8 293.5	3.1 326.4	4.4 460.7
35	20	6.0	120.0	3.750	1.94	2.07 247.92	2.31 277.20	2.6 309.2	2.9 351.2	3.3 390.0	4.6 550.0
36	24	6.4	153.6	4.174	2.04	2.22 341.30	2.48 381.54	2.8 425.0	3.1 482.8	3.5 534.8	4.9 752.2
37	28	6.8	190.4	4.577	2.14	2.36 449.92	2.64 502.85	2.9 559.6	3.3 635.6	3.7 702.8	5.2 986.5
38	32	7.2	230.4	4.966	2.23	2.50 575.08	2.79 642.82	3.1 714.5	3.5 811.5	3.9 895.6	5.4 1255.2
39	36	7.6	273.6	5.344	2.31	2.62 716.56	2.93 801.10	3.3 889.5	3.7 1010.4	4.1 1113.0	5.7 1558.2
40	40	8.0	320.0	5.714	2.39	2.74 875.52	3.06 978.56	3.4 1085.8	3.9 1232.3	4.2 1356.8	5.9 1897.0

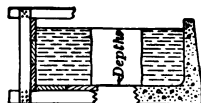
TABLE X.—OPEN RECTANGULAR CHANNELS

## Kutter's Formula

When  $n$  equals .013.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width ins.	Depth ins.	Area sq. ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)	.22361 (264)
1	4	2	.056	.0833	.289	.564 .031	.798 .044	1.262 0.070	1.79 0.10	2.52 0.14	3.99 0.22
2	6	3	.125	.1250	.354	.783 .098	1.107 0.138	1.751 0.219	2.48 0.31	3.50 0.44	5.54 0.69
3	8	4	.222	.1666	.408	.984 .219	1.392 0.309	2.201 0.489	3.11 0.69	4.40 0.98	6.96 1.55
4	10	5	.347	.2083	.456	1.175 0.408	1.661 0.577	2.627 0.912	3.72 1.29	5.25 1.82	8.31 2.88
5	12	6	.500	.2500	.500	1.347 0.674	1.905 0.953	3.012 1.506	4.26 2.13	6.03 3.01	9.53 4.76
6	14	7	.681	.2917	.540	1.532 1.043	2.166 1.474	3.425 2.331	4.84 3.30	6.85 4.66	10.83 7.37
7	16	8	.889	.3333	.577	1.704 1.515	2.410 2.142	3.811 2.387	5.39 4.79	7.62 6.77	12.05 10.71
8	18	9	1.125	.3750	.612	1.833 2.062	2.592 2.916	4.099 4.611	5.80 6.52	8.20 9.22	12.96 14.58
9	20	10	1.389	.4167	.646	1.983 2.764	2.804 3.894	4.434 6.158	6.27 8.71	8.87 12.32	14.02 19.48
10	22	11	1.681	.4583	.677	2.125 3.571	3.006 5.052	4.752 7.986	6.72 11.30	9.51 15.97	15.03 25.26
						.01414 (1.06)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)
11	24	12	2.00	.500	.71	.96 1.93	1.57 3.14	2.26 4.53	3.20 6.40	5.06 10.12	7.16 14.31
12	28	14	2.72	.583	.76	1.08 2.95	1.76 4.78	2.53 6.89	3.58 9.74	5.66 15.40	8.00 21.77
13	32	16	3.56	.667	.82	1.19 4.25	1.94 6.88	2.78 9.88	3.93 13.98	6.22 22.11	8.79 31.26
14	36	18	4.50	.750	.87	1.30 5.86	2.11 9.48	3.02 13.59	4.27 19.22	6.75 30.39	9.55 42.98
15	40	20	5.56	.833	.91	1.41 7.81	2.27 12.60	3.25 18.05	4.59 25.52	7.26 40.36	10.27 57.07
16	44	22	6.72	.917	.96	1.51 10.12	2.43 16.30	3.47 23.32	4.91 32.98	7.76 52.15	10.97 73.75
17	48	24	8.00	1.000	1.00	1.60 12.81	2.58 20.61	3.68 29.47	5.21 41.68	8.24 65.90	11.65 93.20
18	52	26	9.39	1.083	1.04	1.69 15.91	2.72 25.87	3.89 36.53	5.50 51.66	8.70 81.68	12.30 115.51
19	56	28	10.89	1.167	1.08	1.78 19.42	2.86 31.19	4.09 44.53	5.78 62.97	9.14 99.57	12.93 140.82
20	60	30	12.50	1.250	1.12	1.87 23.39	3.00 37.53	4.28 53.54	6.06 75.71	9.58 119.70	13.54 169.29

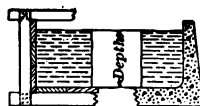
TABLE X.—OPEN RECTANGULAR CHANNELS (Con.)

## Kutter's Formula

When  $n$  equals .013.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width feet	Depth feet	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.00898 (.426)	.01000 (.528)	.01414 (1.06)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)
21	5.5	2.75	15.13	1.375	1.17	1.21 18.36	1.38 20.90	2.00 30.22	3.20 48.40	4.56 68.99	6.45 97.57
22	6.0	3.0	18.00	1.500	1.23	1.30 23.33	1.47 26.50	2.12 33.21	3.40 61.13	4.84 87.07	6.84 123.12
23	6.5	3.25	21.13	1.625	1.28	1.38 29.05	1.56 32.91	2.24 47.38	3.58 75.69	5.10 107.72	7.21 152.33
24	7.0	3.5	24.50	1.750	1.32	1.45 35.55	1.64 40.23	2.36 57.77	3.76 92.17	5.35 131.12	7.57 185.44
25	7.5	3.75	28.13	1.875	1.37	1.53 42.89	1.72 48.43	2.47 69.44	3.94 110.67	5.60 157.36	7.91 222.53
26	8.0	4.0	32.00	2.000	1.41	1.60 51.10	1.80 57.66	2.58 82.53	4.11 131.39	5.83 186.66	8.25 264.00
27	9.0	4.5	40.50	2.250	1.50	1.74 70.43	1.96 79.18	2.79 113.00	4.44 179.66	6.29 254.87	8.90 360.41
28	10.0	5.0	50.00	2.500	1.58	1.87 93.70	2.10 105.05	2.99 149.55	4.75 237.40	6.73 336.40	9.52 475.75
29	11.0	5.1	56.10	2.646	1.63	1.95 109.45	2.18 122.52	3.11 174.19	4.93 276.29	6.98 391.41	9.87 553.45
30	12.0	5.2	62.40	2.786	1.67	2.02 126.24	2.26 141.09	3.21 200.24	5.09 317.49	7.20 449.53	10.19 635.67
31	13	5.3	68.9	2.919	1.71	1.64 113.20	1.84 126.85	2.1 144.1	2.3 160.9	3.3 228.0	5.2 361.2
32	14	5.4	75.6	3.048	1.75	1.69 128.07	1.90 143.41	2.2 162.8	2.4 181.7	3.4 257.3	5.4 407.3
33	16	5.6	89.6	3.294	1.82	1.79 160.38	2.00 179.29	2.3 203.7	2.5 226.7	3.6 320.6	5.7 506.9
34	18	5.8	104.4	3.527	1.88	1.88 196.06	2.10 218.93	2.4 248.7	2.6 276.5	3.7 390.1	5.9 616.1
35	20	6.0	120.0	3.750	1.94	1.96 235.08	2.19 262.32	2.5 298.0	2.8 330.8	3.9 466.2	6.1 735.6
36	24	6.4	153.6	4.174	2.04	2.11 324.40	2.35 361.27	2.7 410.4	3.0 454.5	4.2 639.0	6.6 1007.5
37	28	6.8	190.4	4.577	2.14	2.25 428.59	2.50 476.38	2.8 541.1	3.1 598.0	4.4 839.1	6.9 1321.9
38	32	7.2	230.4	4.966	2.23	2.38 548.35	2.64 609.18	3.0 691.9	3.3 763.3	4.6 1068.8	7.3 1681.7
39	36	7.6	273.6	5.344	2.31	2.50 684.27	2.78 759.51	3.2 862.7	3.5 949.9	4.9 1328.1	7.6 2087.3
40	40	8.0	320.0	5.714	2.39	2.62 836.80	2.90 928.64	3.3 1054.7	3.6 1158.7	5.1 1618.9	7.9 2542.4

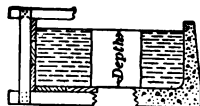
TABLE XI.—OPEN RECTANGULAR CHANNELS

## Kutter's Formula

When  $n$  equals .015.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width ins.	Depth ins.	Area sq. ft.	$r$ feet.	$\sqrt{r}$ feet.	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)	.22361 (264)	.31623 (528)
1	4	2	.056	.0833	.289	.644 0.036	1.019 0.057	1.441 0.080	2.04 0.11	3.22 0.18	4.56 0.25
2	6	3	.125	.1250	.354	.892 0.112	1.410 0.176	1.994 0.249	2.82 0.35	4.46 0.56	6.31 0.79
3	8	4	.222	.1666	.408	1.148 0.255	1.815 0.403	2.567 0.570	3.63 0.81	5.74 1.28	8.12 1.80
4	10	5	.347	.2083	.456	1.377 0.478	2.176 0.756	3.078 1.069	4.35 1.51	6.88 2.39	9.73 3.38
5	12	6	.500	.2500	.500	1.583 0.792	2.503 1.252	3.540 1.770	5.01 2.50	7.92 3.96	11.19 5.60
6	14	7	.681	.2917	.540	1.791 1.219	2.831 1.927	4.004 2.735	5.66 3.85	8.95 6.09	12.66 8.62
7	16	8	.889	.3333	.577	1.984 1.763	3.137 2.788	4.437 3.944	6.28 5.58	9.92 8.82	14.03 12.47
8	18	9	1.125	.3750	.612	2.169 2.440	3.430 3.859	4.851 5.457	6.86 7.72	10.85 12.20	15.34 17.26
9	20	10	1.389	.4167	.646	2.350 3.264	3.716 5.161	5.255 7.299	7.43 10.32	11.75 16.32	16.62 23.08
10	22	11	1.681	.4583	.677	2.522 4.238	3.987 6.701	5.639 9.477	7.98 13.40	12.61 21.19	17.83 29.97
						.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)
11	24	12	2.00	.500	.71	1.32 2.64	1.90 3.80	2.69 5.38	4.25 8.50	6.01 12.02	8.50 17.00
12	28	14	2.72	.583	.76	1.48 4.03	2.13 5.80	3.02 8.21	4.77 12.98	6.74 18.35	9.54 25.95
13	32	16	3.56	.667	.82	1.63 5.81	2.35 8.35	3.32 11.81	5.25 18.68	7.43 26.41	10.51 37.35
14	36	18	4.50	.750	.87	1.78 8.02	2.56 11.51	3.62 16.28	5.72 25.74	8.09 36.40	11.44 51.47
15	40	20	5.56	.833	.91	1.92 10.68	2.76 15.32	3.90 21.66	6.16 34.24	8.72 48.43	12.33 68.49
16	44	22	6.72	.917	.96	2.06 13.84	2.95 19.82	4.17 28.04	6.59 44.33	9.33 62.69	13.19 88.66
17	48	24	8.00	1.000	1.00	2.19 17.51	3.13 25.07	4.43 35.46	7.01 56.06	9.91 79.28	14.02 112.12
18	52	26	9.39	1.083	1.04	2.32 21.76	3.32 31.13	4.69 44.03	7.41 69.61	10.49 98.44	14.83 139.22
19	56	28	10.89	1.167	1.08	2.44 26.59	3.49 38.01	4.94 53.76	7.81 85.00	11.04 130.20	15.61 169.99
20	60	30	12.50	1.250	1.12	2.56 32.03	3.66 45.76	5.18 64.71	8.19 102.31	11.58 144.70	16.37 204.64

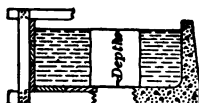
TABLE XI.—OPEN RECTANGULAR CHANNELS (Con.)

## Kutter's Formula

When  $n$  equals .015.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



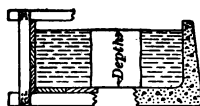
No.	Width feet	Depth feet	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01000 (.528)	.01414 (1.06)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)
21	5.5	2.75	15.13	1.375	1.17	1.18	1.71	2.74	3.90	5.52	8.73
22	6.0	3.0	18.00	1.500	1.23	17.85	25.83	41.38	59.03	83.48	133.00
23	6.5	3.25	21.13	1.625	1.28	1.26	1.82	2.91	4.14	5.86	9.27
24	7.0	3.5	24.50	1.750	1.32	22.66	32.71	52.34	74.59	108.50	166.81
25	7.5	3.75	28.13	1.875	1.37	1.33	1.92	3.07	4.38	6.19	9.78
26	8.0	4.0	32.00	2.000	1.41	28.18	40.60	64.88	92.42	130.70	206.67
27	9.0	4.5	40.50	2.250	1.50	1.41	2.02	3.23	4.60	6.50	10.28
28	10.0	5.0	50.00	2.500	1.58	34.47	49.56	79.14	112.63	159.30	251.86
29	11.0	5.1	56.10	2.646	1.63	1.48	2.12	3.38	4.81	6.80	10.76
30	12.0	5.2	62.40	2.786	1.67	41.57	59.68	95.15	135.31	191.36	302.57
31	13	5.3	68.9	2.919	1.71	1.55	2.22	3.53	5.02	7.10	11.23
32	14	5.4	75.6	3.048	1.75	49.54	70.98	113.06	160.67	227.23	359.30
33	16	5.6	89.6	3.294	1.82	1.68	2.40	3.82	5.43	7.67	12.13
34	18	5.8	104.4	3.527	1.88	68.16	97.36	154.75	219.79	310.80	491.43
35	20	6.0	120.0	3.750	1.94	1.81	2.58	4.10	5.81	8.22	12.99
36	24	6.4	153.6	4.174	2.04	90.65	129.00	204.85	290.55	410.85	649.65
37	28	6.8	190.4	4.577	2.14	1.89	2.68	4.25	6.03	8.53	13.48
38	32	7.2	230.4	4.966	2.23	105.86	150.46	238.65	338.23	478.31	756.28
39	36	7.6	273.6	5.344	2.31	1.96	2.78	4.40	6.23	8.81	13.93
40	40	8.0	320.0	5.714	2.39	121.99	173.16	274.50	388.63	549.62	868.98
31	13	5.3	68.9	2.919	1.71	.00791 (.33)	.00898 (.426)	.01000 (.528)	.01414 (1.06)	.02236 (2.64)	.03162 (5.28)
32	14	5.4	75.6	3.048	1.75	1.59	1.81	2.0	2.9	4.5	6.4
33	16	5.6	89.6	3.294	1.82	109.69	124.64	139.2	197.3	312.6	442.3
34	18	5.8	104.4	3.527	1.88	1.64	1.87	2.1	2.9	4.7	6.6
35	20	6.0	120.0	3.750	1.94	124.14	140.99	157.2	222.8	352.7	498.8
36	24	6.4	153.6	4.174	2.04	1.73	1.97	2.2	3.1	4.9	6.9
37	28	6.8	190.4	4.577	2.14	155.37	176.42	196.5	277.9	439.4	621.2
38	32	7.2	230.4	4.966	2.23	1.82	2.07	2.3	3.2	5.1	7.2
39	36	7.6	273.6	5.344	2.31	189.90	215.69	239.9	338.7	534.8	756.0
40	40	8.0	320.0	5.714	2.39	1.90	2.16	2.4	3.4	5.3	7.5
31	13	5.3	68.9	2.919	1.71	227.88	258.84	287.3	408.0	639.0	902.9
32	14	5.4	75.6	3.048	1.75	2.05	2.33	2.6	3.6	5.7	8.0
33	16	5.6	89.6	3.294	1.82	314.42	357.12	395.4	555.6	875.7	1236.0
34	18	5.8	104.4	3.527	1.88	2.18	2.48	2.7	3.8	6.0	8.5
35	20	6.0	120.0	3.750	1.94	415.26	471.81	520.9	730.6	1150.4	1622.2
36	24	6.4	153.6	4.174	2.04	2.31	2.62	2.9	4.0	6.4	9.0
37	28	6.8	190.4	4.577	2.14	531.76	603.88	665.6	932.2	1465.8	2065.3
38	32	7.2	230.4	4.966	2.23	2.43	2.76	3.0	4.2	6.7	9.4
39	36	7.6	273.6	5.344	2.31	663.48	753.77	829.3	1159.2	1821.4	2563.6
40	40	8.0	320.0	5.714	2.39	2.54	2.88	3.2	4.4	6.9	9.8
31	13	5.3	68.9	2.919	1.71	812.16	922.24	1013.1	1413.4	2218.9	3123.8

TABLE XII.—KUTTER'S FORMULA

FOR OPEN RECTANGULAR CHANNELS AND TIMBER FLUMES

Conduits carrying 5 ft. or less of water are twice as wide as deep.

In all conduits that carry more than 5 ft. of water the width is increased at an advancing ratio when compared with the depth.



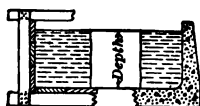
Quantity or Vol. of the Flow.	Width ins.	Depth ins.	$\sqrt{r}$ feet	Area sq. ft.	Mean Velocity Feet per Sec.	Grade, or Fall in Feet per Mile when			$\zeta$ N
						$n = .011$	$n = .013$	$n = .015$	
.50	4	2	.2886	.056	8.99	851.0	1339.0	2055.0	1
sec.-ft.	6	3	.3536	.125	4.00	87.3	138.0	212.0	2
or	8	4	.4082	.222	2.25	17.7	27.6	40.6	3
20	10	5	.4564	.347	1.44	5.12	7.92	11.6	4
inches	12	6	.5000	.500	1.00	2.00	3.06	4.22	5
.75	6	3	.3536	.125	6.00	197.0	310.0	478.0	6
sec.-ft.	8	4	.4082	.222	3.38	40.0	62.3	91.6	7
or	10	5	.4564	.347	2.16	11.6	17.8	26.0	8
30	12	6	.5000	.500	1.50	4.28	6.55	9.50	9
inches	16	8	.5773	.889	0.84	0.95	1.48	2.00	10
1.25	8	4	.4082	.222	5.63	111.0	173.0	254.0	11
sec.-ft.	10	5	.4564	.347	3.60	32.1	49.6	72.2	12
or	12	6	.5000	.500	2.50	11.8	18.2	26.3	13
50	16	8	.5773	.889	1.41	2.58	3.64	5.33	14
inches	20	10	.6455	1.389	0.90	0.79	1.21	1.64	15
1.75	10	5	.4564	.347	5.04	62.9	97.2	142.0	16
sec.-ft.	12	6	.5000	.500	3.50	23.2	35.6	51.6	17
or	16	8	.5773	.889	1.97	4.80	7.08	10.4	18
70	20	10	.6455	1.389	1.26	1.58	2.22	3.11	19
inches	24	12	.7071	2.000	0.88	0.63	0.90	1.27	20
2.50	12	6	.5000	.500	5.00	47.4	72.7	105.0	21
sec.-ft.	14	7	.5400	.681	3.67	20.2	30.3	44.4	22
or	18	9	.6124	1.125	2.22	5.13	7.75	11.1	23
100	24	12	.7071	2.000	1.25	1.18	1.68	2.38	24
inches	28	14	.7637	2.722	0.92	0.56	0.77	1.08	25
3.75	14	7	.5400	.681	5.51	45.6	68.3	100.0	26
sec.-ft.	18	9	.6124	1.125	3.33	11.5	17.4	24.9	27
or	22	11	.6770	1.681	2.23	3.88	5.81	8.26	28
150	28	14	.7637	2.722	1.38	1.15	1.63	2.29	29
inches	36	18	.8660	4.500	0.83	0.35	0.46	0.60	30
5.00	16	8	.5773	.889	5.63	39.1	57.6	85.0	31
sec.-ft.	20	10	.6455	1.389	3.60	11.6	17.4	24.8	32
or	24	12	.7071	2.000	2.50	4.31	6.45	9.13	33
200	32	16	.8165	3.556	1.41	0.99	1.47	1.96	34
inches	40	20	.9129	5.556	0.90	0.35	0.46	0.60	35
7.50	18	9	.6124	1.125	6.67	46.3	69.9	99.8	36
sec.-ft.	22	11	.6770	1.681	4.46	15.5	23.3	33.0	37
or	28	14	.7637	2.722	2.76	4.24	6.29	8.85	38
300	36	18	.8660	4.500	1.67	1.18	1.74	2.32	39
inches	48	24	1.0000	8.000	0.94	0.29	0.39	0.51	40
12.5	24	12	.707	2.000	6.25	27.0	40.3	57.1	41
sec.-ft.	28	14	.764	2.722	4.59	11.7	17.4	24.5	42
or	36	18	.866	4.500	2.78	3.13	4.47	6.24	43
500	48	24	1.000	8.000	1.56	0.73	1.00	1.39	44
inches	60	30	1.118	12.500	1.00	0.24	0.32	0.41	45
17.5	28	14	.764	2.722	6.43	23.0	34.1	48.0	46
sec.-ft.	36	18	.866	4.500	3.89	5.96	8.76	12.2	47
or	48	24	1.000	8.000	2.19	1.36	1.91	2.64	48
700	60	30	1.118	12.500	1.40	0.43	0.62	0.81	49
inches	72	36	1.225	18.000	0.97	0.17	0.24	0.33	50

TABLE XII.—KUTTER'S FORMULA (Con.)

FOR OPEN RECTANGULAR CHANNELS AND TIMBER FLUMES

Conduits carrying 5 ft. or less of water are twice as wide as deep.

In all conduits that carry more than 5 ft. of water the width is increased at an advancing ratio when compared with the depth.



Quantity or Vol. of the Flow.	Width feet	Depth feet	$\sqrt{r}$ feet	Area sq.ft.	Mean Velocity Feet per Sec.	Grade, or Fall in Feet per Mile when			$\delta$ Z
						$n=.011$	$n=.013$	$n=.015$	
25.0	3.	1.5	.866	4.50	5.56	12.2	17.9	25.0	51
sec.-ft.	4.	2.	1.000	8.00	3.13	2.68	3.81	5.27	52
or	5.	2.5	1.118	12.50	2.00	0.83	1.21	1.61	53
1000	6.	3.	1.225	18.00	1.39	0.34	0.47	0.64	54
inches	7.	3.5	1.323	24.50	1.02	0.15	0.22	0.29	55
37.5	3.67	1.83	.958	6.72	5.58	9.36	13.7	18.9	56
sec.-ft.	4.33	2.16	1.041	9.39	3.99	3.83	5.55	7.65	57
or	5.5	2.75	1.172	15.13	2.48	1.13	1.58	2.17	58
1500	7.	3.5	1.323	24.50	1.53	0.33	0.46	0.62	59
inches	9.	4.5	1.500	40.50	0.93	0.08	0.12	0.17	60
50	4.	2.	1.000	8.00	6.25	10.5	15.2	21.0	61
sec.-ft.	5.	2.5	1.118	12.50	4.00	3.24	4.60	6.30	62
or	6.	3.	1.225	18.00	2.78	1.26	1.76	2.41	63
2000	8.	4.	1.414	32.00	1.56	0.29	0.41	0.54	64
inches	10.	5.	1.581	50.00	1.00	0.08	0.12	0.16	65
75	5.	2.5	1.118	12.50	6.00	7.19	10.4	14.2	66
sec.-ft.	6.	3.	1.225	18.00	4.17	2.77	3.92	5.35	67
or	8.	4.	1.414	32.00	2.34	0.63	0.87	1.18	68
3000	10.	5.	1.581	50.00	1.50	0.20	0.27	0.36	69
inches	12.	5.2	1.669	62.40	1.20	0.11	0.15	0.20	70
125	6.	3.	1.225	18.00	6.94	7.58	10.9	14.8	71
sec.-ft.	8.	4.	1.414	32.00	3.91	1.68	2.39	3.23	72
or	10.	5.	1.581	50.00	2.50	0.53	0.75	0.99	73
5000	12.	5.2	1.669	62.40	2.00	0.30	0.42	0.55	74
inches	14.	5.4	1.746	75.60	1.65	0.18	0.25	0.33	75
175	7.	3.5	1.323	24.50	7.14	6.59	9.40	12.7	76
sec.-ft.	9.	4.5	1.500	40.50	4.32	1.77	2.50	3.37	77
or	12.	5.2	1.669	62.40	2.80	0.58	0.80	1.08	78
7000	14.	5.4	1.746	75.60	2.31	0.35	0.49	0.65	79
inches	16.	5.6	1.815	89.60	1.95	0.23	0.31	0.42	80
250	8.	4.	1.414	32.00	7.81	6.67	9.47	12.8	81
sec.-ft.	10.	5.	1.581	50.00	5.00	2.08	2.93	3.93	82
or	12.	5.2	1.669	62.40	4.01	1.17	1.64	2.19	83
10,000	16.	5.6	1.815	89.60	2.79	0.46	0.64	0.86	84
inches	20.	6.	1.936	120.00	2.08	0.22	0.30	0.40	85
375	10.	5.	1.581	50.00	7.50	4.66	6.56	8.80	86
sec.-ft.	12.	5.2	1.669	62.40	6.01	2.62	3.67	4.92	87
or	14.	5.4	1.746	75.60	4.96	1.60	2.24	2.98	88
15,000	18.	5.8	1.878	104.40	3.59	0.70	0.98	1.29	89
inches	24.	6.4	2.043	153.60	2.44	0.25	0.35	0.48	90
500	14.	5.4	1.746	75.60	6.61	2.84	3.97	5.30	91
sec.-ft.	16.	5.6	1.815	89.60	5.58	1.84	2.57	3.42	92
or	20.	6.	1.936	120.00	4.17	0.88	1.21	1.62	93
20,000	24.	6.4	2.043	153.60	3.26	0.46	0.64	0.86	94
inches	32.	7.2	2.229	230.40	2.17	0.16	0.22	0.29	95
750	18.	5.8	1.878	104.40	7.18	2.80	3.91	5.19	96
sec.-ft.	20.	6.	1.936	120.00	6.25	1.97	2.74	3.64	97
or	24.	6.4	2.043	153.60	4.88	1.05	1.45	1.93	98
30,000	32.	7.2	2.229	230.40	3.26	0.36	0.51	0.67	99
inches	40.0	8.	2.390	320.00	2.34	0.15	0.21	0.27	100

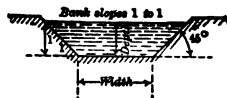
TABLE XIII.—OPEN TRAPEZOIDAL CHANNELS

## Bazin's First Form

FOR EVEN SURFACES, PLANED PLANKS, ETC.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width ins.	Depth ins.	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)
1	26	13	3.52	.673	.82	1.27	1.46	1.79	2.53	3.58	5.07
						<b>4.46</b>	<b>5.15</b>	<b>6.31</b>	<b>8.92</b>	<b>12.62</b>	<b>17.84</b>
2	28	14	4.08	.725	.85	1.32	1.53	1.87	2.64	3.74	5.28
						<b>5.39</b>	<b>6.23</b>	<b>7.63</b>	<b>10.79</b>	<b>15.26</b>	<b>21.58</b>
3	30	15	4.69	.777	.88	1.37	1.59	1.94	2.75	3.88	5.49
						<b>6.44</b>	<b>7.43</b>	<b>9.10</b>	<b>12.87</b>	<b>18.20</b>	<b>25.74</b>
4	32	16	5.33	.828	.91	1.42	1.64	2.01	2.85	4.02	5.69
						<b>7.59</b>	<b>8.76</b>	<b>10.73</b>	<b>15.18</b>	<b>21.46</b>	<b>30.35</b>
5	34	17	6.02	.880	.94	1.47	1.70	2.08	2.94	4.16	5.89
						<b>8.86</b>	<b>10.23</b>	<b>12.53</b>	<b>17.71</b>	<b>25.05</b>	<b>35.43</b>
6	36	18	6.75	.932	.97	1.52	1.75	2.15	3.04	4.29	6.07
						<b>10.25</b>	<b>11.83</b>	<b>14.49</b>	<b>20.49</b>	<b>28.99</b>	<b>40.99</b>
7	40	20	8.33	1.036	1.02	1.61	1.86	2.27	3.22	4.55	6.43
						<b>13.40</b>	<b>15.48</b>	<b>18.95</b>	<b>26.80</b>	<b>37.90</b>	<b>53.60</b>
8	44	22	10.08	1.139	1.07	1.69	1.96	2.39	3.39	4.79	6.77
						<b>17.07</b>	<b>19.71</b>	<b>24.14</b>	<b>34.14</b>	<b>48.29</b>	<b>68.28</b>
9	48	24	12.00	1.243	1.12	1.77	2.05	2.51	3.55	5.02	7.10
						<b>21.29</b>	<b>24.59</b>	<b>30.11</b>	<b>42.58</b>	<b>60.22</b>	<b>85.16</b>
10	52	26	14.08	1.346	1.16	1.85	2.14	2.62	3.70	5.24	7.41
						<b>26.08</b>	<b>30.11</b>	<b>36.88</b>	<b>52.17</b>	<b>73.77</b>	<b>104.33</b>

TABLE XIII.—OPEN TRAPEZOIDAL CHANNELS (Con.)

## Bazin's First Form

FOR EVEN SURFACES, PLANED PLANKS, ETC.



Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.

No.	Width feet	Depth feet	Area sq.ft.	r feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)
11	4.5	2.25	17.72	1.405	1.19	1.70	1.90	2.19	2.68	3.79	5.36
12	5.0	2.5	21.88	1.561	1.25	30.03	33.58	38.77	47.47	67.14	94.96
13	5.5	2.6	24.44	1.643	1.28	1.79	2.00	2.31	2.83	4.01	5.67
14	6.0	2.7	27.14	1.725	1.31	39.20	43.84	50.62	61.99	87.66	123.97
15	6.5	2.8	29.96	1.805	1.34	1.84	2.06	2.38	2.91	4.12	5.82
16	7.0	2.9	32.92	1.886	1.37	44.99	50.32	58.09	71.15	100.62	142.31
17	7.5	3.0	36.00	1.965	1.40	1.89	2.11	2.44	2.99	4.23	5.97
18	8.0	3.1	39.22	2.045	1.43	51.26	57.31	66.18	81.05	114.66	162.11
19	9.0	3.2	44.16	2.150	1.47	1.94	2.16	2.50	3.06	4.33	6.12
20	10.0	3.3	49.34	2.253	1.50	57.97	64.80	74.84	91.65	129.64	183.33
21	11.0	3.4	54.7	2.354	1.53	1.98	2.21	2.56	3.13	4.43	6.26
22	12.0	3.5	60.4	2.452	1.57	65.17	72.87	84.13	103.06	145.72	206.08
23	13.0	3.6	66.2	2.550	1.60	2.02	2.26	2.61	3.20	4.52	6.40
24	14.0	3.7	72.3	2.646	1.63	72.83	81.43	94.03	115.16	162.86	230.33
25	15.0	3.8	78.5	2.746	1.67	2.07	2.31	2.67	3.27	4.62	6.53
26	16.0	3.9	84.8	2.846	1.70	81.02	90.59	104.59	128.08	181.13	256.19
27	17.0	4.0	91.2	2.946	1.74	2.12	2.37	2.74	3.35	4.74	6.71
28	18.0	4.1	97.7	3.046	1.77	93.66	104.70	120.91	148.07	209.41	296.14
29	19.0	4.2	104.3	3.146	1.80	2.17	2.43	2.81	3.44	4.86	6.87
30	20.0	4.3	111.0	3.246	1.83	107.21	119.84	138.39	169.52	239.72	338.98
31	21.0	4.4	117.7	3.346	1.86	2.23	2.48	2.87	3.52	4.97	7.00
32	22.0	4.5	124.6	3.446	1.89	109.26	121.69	136.03	157.10	192.41	272.11
33	23.0	4.6	131.6	3.546	1.92	2.04	2.27	2.64	3.24	4.58	6.50
34	24.0	4.7	138.7	3.646	1.95	123.11	137.11	153.29	176.96	216.75	306.52
35	25.0	4.8	145.9	3.746	1.98	2.08	2.32	2.69	3.29	4.66	6.58
36	26.0	4.9	153.2	3.846	2.01	137.85	153.48	171.63	198.19	243.70	343.26
37	27.0	5.0	160.6	3.946	2.04	2.12	2.36	2.74	3.35	4.74	6.71
38	28.0	5.1	168.1	4.046	2.07	153.42	170.86	191.04	220.62	270.17	382.07
39	29.0	5.2	175.7	4.146	2.10	2.18	2.42	2.81	3.44	4.86	6.87
40	30.0	5.3	183.4	4.246	2.13	179.35	199.72	223.22	257.77	315.74	446.52
41	31.0	5.4	191.2	4.346	2.16	2.23	2.48	2.87	3.52	4.97	7.00
42	32.0	5.5	199.1	4.446	2.19	206.96	230.40	257.65	297.46	364.34	515.21
43	33.0	5.6	207.1	4.546	2.22	2.27	2.53	2.93	3.67	5.14	7.21
44	34.0	5.7	215.2	4.646	2.25	236.29	263.12	294.11	339.66	416.00	583.22
45	35.0	5.8	223.4	4.746	2.28	2.32	2.58	2.98	3.73	5.24	7.34
46	36.0	5.9	231.7	4.846	2.31	267.42	297.77	332.86	384.33	470.78	665.71
47	37.0	6.0	240.1	4.946	2.34	2.36	2.63	2.94	3.39	4.15	5.87
48	38.0	6.1	248.6	5.046	2.37	300.21	334.31	373.76	431.67	528.64	747.53
49	39.0	6.2	257.2	5.146	2.40	2.40	2.67	2.99	3.45	4.23	5.98
50	40.0	6.3	265.9	5.246	2.43	334.88	372.98	416.93	481.54	589.66	834.00

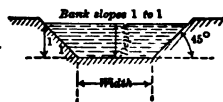
TABLE XIV.—OPEN TRAPEZOIDAL CHANNELS

## Bazin's Second Form

FOR UNPLANED PLANK, CUT STONE, BRICK, ETC.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.

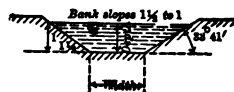


No.	Width ins.	Depth ins.	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)
1	26	13	3.52	.673	.82	1.202 <b>4.232</b>	1.472 <b>5.183</b>	2.082 <b>7.330</b>	2.944 <b>10.365</b>	4.163 <b>14.657</b>	6.58 <b>23.18</b>
2	28	14	4.08	.725	.85	1.259 <b>5.141</b>	1.542 <b>6.296</b>	2.180 <b>8.902</b>	3.083 <b>12.589</b>	4.360 <b>17.808</b>	6.89 <b>25.15</b>
3	30	15	4.69	.777	.88	1.313 <b>6.155</b>	1.609 <b>7.542</b>	2.275 <b>10.664</b>	3.217 <b>15.080</b>	4.550 <b>21.328</b>	7.19 <b>32.72</b>
4	32	16	5.33	.828	.91	1.366 <b>7.285</b>	1.673 <b>8.923</b>	2.366 <b>12.619</b>	3.347 <b>17.851</b>	4.733 <b>25.243</b>	7.48 <b>39.91</b>
5	34	17	6.02	.880	.94	1.417 <b>8.532</b>	1.736 <b>10.453</b>	2.455 <b>14.782</b>	3.472 <b>20.905</b>	4.910 <b>29.563</b>	7.76 <b>46.74</b>
6	36	18	6.75	.932	.97	1.467 <b>9.902</b>	1.797 <b>12.130</b>	2.541 <b>17.152</b>	3.593 <b>24.253</b>	5.082 <b>34.304</b>	8.04 <b>54.24</b>
7	40	20	8.33	1.036	1.02	1.562 <b>13.017</b>	1.913 <b>15.942</b>	2.705 <b>22.542</b>	3.826 <b>31.833</b>	5.410 <b>45.083</b>	8.55 <b>71.28</b>
8	44	22	10.08	1.139	1.07	1.652 <b>16.657</b>	2.023 <b>20.398</b>	2.861 <b>28.848</b>	4.046 <b>40.797</b>	5.722 <b>57.696</b>	9.05 <b>91.22</b>
9	48	24	12.00	1.243	1.12	1.737 <b>20.844</b>	2.128 <b>25.536</b>	3.009 <b>36.108</b>	4.256 <b>51.072</b>	6.018 <b>72.216</b>	9.52 <b>114.19</b>
10	52	26	14.08	1.346	1.16	1.819 <b>25.618</b>	2.228 <b>31.378</b>	3.151 <b>44.377</b>	4.456 <b>62.755</b>	6.302 <b>88.753</b>	9.97 <b>140.34</b>

TABLE XIV.—OPEN TRAPEZOIDAL CHANNELS (Con.)

## Bazin's Second Form

FOR UNPLANED PLANK, CUT STONE, BRICK, ETC.



Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.

No.	Width feet	Depth feet	Area sq. ft.	r feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)
11	4.5	2.25	17.72	1.405	1.19	1.62 28.62	1.86 33.03	2.28 40.45	3.23 57.22	4.57 80.92	6.46 114.43
12	5.0	2.5	21.88	1.561	1.25	1.71 37.49	1.98 43.29	2.42 53.03	3.43 74.99	4.85 106.05	6.86 149.95
13	5.5	2.6	24.44	1.643	1.28	1.76 43.11	2.04 49.78	2.50 60.98	3.53 86.22	4.99 121.93	7.06 172.45
14	6.0	2.7	27.14	1.725	1.31	1.81 49.20	2.09 56.79	2.56 69.57	3.63 98.36	5.13 139.12	7.25 196.76
15	6.5	2.8	29.96	1.805	1.34	1.86 55.70	2.15 64.32	2.63 78.77	3.72 111.39	5.26 157.53	7.44 223.81
16	7.0	2.9	32.92	1.886	1.37	1.91 62.70	2.20 72.41	2.69 88.67	3.81 125.41	5.39 177.35	7.62 250.81
17	7.5	3.0	36.00	1.965	1.40	1.95 70.16	2.25 81.00	2.76 99.22	3.90 140.33	5.51 198.43	7.80 280.62
18	8.0	3.1	39.22	2.045	1.43	1.99 78.12	2.30 90.20	2.82 110.47	3.98 156.23	5.64 220.98	7.97 312.47
19	9.0	3.2	44.16	2.150	1.47	2.05 90.44	2.36 104.39	2.90 127.89	4.10 180.84	5.79 255.78	8.19 361.72
20	10.0	3.3	49.34	2.253	1.50	2.10 103.65	2.43 119.69	2.97 146.57	4.20 207.31	5.94 293.15	8.40 414.56
21	11.0	3.4	54.7	2.354	1.53	1.93 105.38	2.15 117.80	2.49 136.03	3.04 166.57	4.30 235.55	6.1 333.2
22	12.0	3.5	60.4	2.452	1.57	1.97 118.82	2.20 132.83	2.54 153.35	3.11 187.83	4.40 265.65	6.2 375.7
23	13.0	3.6	66.2	2.550	1.60	2.01 133.14	2.25 148.84	2.60 171.89	3.18 210.51	4.49 297.68	6.4 421.0
24	14.0	3.7	72.3	2.646	1.63	2.05 148.29	2.29 165.79	2.65 191.47	3.24 234.51	4.59 331.66	6.5 469.0
25	16.0	3.8	82.5	2.776	1.67	2.10 173.50	2.35 194.03	2.72 223.96	3.33 274.34	4.71 387.97	6.7 548.7
26	18.0	3.9	93.0	2.901	1.70	2.16 200.45	2.41 224.07	2.78 258.77	3.41 316.90	4.82 448.15	6.8 633.7
27	20.0	4.0	104.0	3.021	1.74	2.20 229.01	2.46 256.05	2.84 295.67	3.48 362.02	4.92 512.10	7.0 724.2
28	22.0	4.1	115.4	3.138	1.77	2.25 259.34	2.51 289.92	2.90 334.82	3.55 410.07	5.03 579.96	7.1 820.1
29	24.0	4.2	127.3	3.251	1.80	2.29 291.43	2.56 325.79	2.96 376.18	3.62 460.81	5.12 651.57	7.2 921.5
30	26.0	4.3	139.5	3.362	1.83	2.33 325.26	2.61 363.63	3.01 420.00	3.69 514.33	5.21 727.40	7.4 1028.7

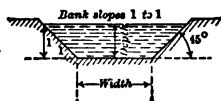
TABLE XV.—OPEN TRAPEZOIDAL CHANNELS

## Bazin's Third Form

FOR UNEVEN SURFACES, RUBBLE MASONRY, ETC.

Light type, the mean velocity in ft. per sec.

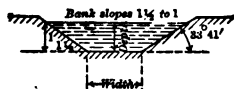
Heavy type, the discharge in cu.ft. per sec.



No.	Width ins.	Depth ins.	Area sq. ft.	feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)
1	26	13	3.52	.673	.82	1.018 <b>3.584</b>	1.440 <b>5.070</b>	2.037 <b>7.172</b>	2.880 <b>10.140</b>	4.55 <b>16.03</b>	6.44 <b>22.67</b>
2	28	14	4.08	.725	.85	1.078 <b>4.402</b>	1.525 <b>6.227</b>	2.156 <b>8.804</b>	3.049 <b>12.450</b>	4.82 <b>19.69</b>	6.82 <b>27.84</b>
3	30	15	4.69	.777	.88	1.136 <b>5.325</b>	1.607 <b>7.533</b>	2.272 <b>10.650</b>	3.214 <b>15.066</b>	5.08 <b>23.82</b>	7.19 <b>33.63</b>
4	32	16	5.33	.828	.91	1.193 <b>6.363</b>	1.687 <b>8.997</b>	2.386 <b>12.725</b>	3.374 <b>17.995</b>	5.33 <b>28.45</b>	7.54 <b>40.23</b>
5	34	17	6.02	.880	.94	1.248 <b>7.514</b>	1.765 <b>10.627</b>	2.496 <b>15.028</b>	3.530 <b>21.254</b>	5.58 <b>33.60</b>	7.89 <b>47.52</b>
6	36	18	6.75	.932	.97	1.302 <b>8.789</b>	1.841 <b>12.427</b>	2.603 <b>17.570</b>	3.682 <b>24.854</b>	5.82 <b>39.29</b>	8.23 <b>55.57</b>
7	40	20	8.33	1.036	1.02	1.405 <b>11.708</b>	1.987 <b>16.558</b>	2.811 <b>23.425</b>	3.975 <b>33.125</b>	6.29 <b>52.33</b>	8.89 <b>74.07</b>
8	44	22	10.08	1.139	1.07	1.505 <b>15.175</b>	2.128 <b>21.457</b>	3.009 <b>30.340</b>	4.255 <b>42.904</b>	6.73 <b>67.84</b>	9.52 <b>95.94</b>
9	48	24	12.00	1.243	1.12	1.600 <b>19.200</b>	2.262 <b>27.144</b>	3.199 <b>38.388</b>	4.524 <b>54.288</b>	7.15 <b>85.84</b>	10.12 <b>121.39</b>
10	52	26	14.08	1.346	1.16	1.691 <b>23.815</b>	2.391 <b>33.673</b>	3.382 <b>47.630</b>	4.783 <b>67.360</b>	7.56 <b>106.50</b>	10.69 <b>150.61</b>

TABLE XV.—OPEN TRAPEZOIDAL CHANNELS (Con.)

## Bazin's Third Form

FOR UNEVEN SURFACES, RUBBLE MASONRY,  
ETC.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.

No.	Width feet	Depth feet	Area sq.ft.	r feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)
11	4.5	2.25	17.72	1.405	1.19	1.422 25.196	1.74 30.85	2.46 43.64	3.48 61.72	4.93 87.27	7.79 137.98
12	5.0	2.5	21.88	1.561	1.25	1.527 33.403	1.87 40.91	2.65 57.86	3.74 81.81	5.29 115.72	8.36 182.96
13	5.5	2.6	24.44	1.643	1.28	1.580 38.615	1.94 47.29	2.74 66.89	3.87 94.61	5.47 133.79	8.66 211.53
14	6.0	2.7	27.14	1.725	1.31	1.632 44.284	2.00 54.24	2.83 76.71	4.00 108.49	5.65 153.42	8.94 242.59
15	6.5	2.8	29.96	1.805	1.34	1.682 50.393	2.06 61.72	2.91 87.27	4.12 123.41	5.83 174.52	9.21 275.96
16	7.0	2.9	32.92	1.886	1.37	1.731 56.976	2.12 69.78	3.00 98.65	4.24 139.53	6.00 197.33	9.48 312.00
17	7.5	3.0	36.00	1.965	1.40	1.777 63.972	2.18 78.37	3.08 110.81	4.35 156.74	6.16 221.65	9.74 350.46
18	8.0	3.1	39.22	2.045	1.43	1.824 71.528	2.23 87.61	3.16 123.88	4.47 175.17	6.32 247.72	9.99 391.72
19	9.0	3.2	44.16	2.150	1.47	1.883 83.153	2.31 101.83	3.26 144.05	4.61 203.71	6.52 288.06	10.31 458.47
20	10.0	3.3	49.34	2.253	1.50	1.940 95.710	2.38 117.22	3.36 165.77	4.75 234.44	6.72 331.53	10.63 524.23
21	11.0	3.4	54.7	2.354	1.53	1.73 94.54	2.00 109.21	2.44 133.73	3.46 189.13	4.89 267.41	6.9 378.2
22	12.0	3.5	60.4	2.452	1.57	1.77 106.99	2.05 123.53	2.51 151.30	3.54 213.97	5.01 302.60	7.1 427.9
23	13.0	3.6	66.2	2.550	1.60	1.82 120.29	2.10 138.91	2.57 170.10	3.63 240.58	5.14 340.21	7.3 481.1
24	14.0	3.7	72.3	2.646	1.63	1.86 134.40	2.15 155.16	2.63 190.10	3.72 268.80	5.26 380.12	7.4 537.6
25	16.0	3.8	82.5	2.776	1.67	1.91 187.83	2.21 182.24	2.71 223.14	3.83 315.57	5.41 446.36	7.7 631.2
26	18.0	3.9	93.0	2.901	1.70	1.97 182.87	2.27 211.14	2.78 258.58	3.93 365.74	5.56 517.26	7.9 731.5
27	20.0	4.0	104.0	3.021	1.74	2.02 209.56	2.33 242.01	2.85 296.40	4.03 419.12	5.70 592.70	8.1 838.2
28	22.0	4.1	115.4	3.138	1.77	2.06 237.99	2.38 274.80	2.92 336.55	4.12 475.97	5.83 673.10	8.3 951.9
29	24.0	4.2	127.3	3.251	1.80	2.11 268.01	2.43 309.50	2.98 397.11	4.21 586.15	5.96 758.22	8.4 1072.2
30	26.0	4.3	139.5	3.362	1.83	2.15 299.86	2.48 346.33	3.04 424.05	4.30 599.72	6.08 848.23	8.6 1199.6

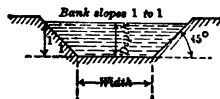
TABLE XVI.—OPEN TRAPEZOIDAL CHANNELS

**Bazin's Fourth Form**

FOR UNEVEN SURFACES, LOOSE EARTH, ETC.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.

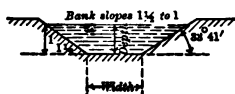


No.	Width ins.	Depth ins.	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)
1	26	13	3.52	.673	.82	.746 <b>2.626</b>	1.055 <b>3.714</b>	1.491 <b>5.249</b>	2.358 <b>8.302</b>	3.335 <b>11.742</b>	4.72 <b>16.60</b>
2	28	14	4.08	.725	.85	.799 <b>3.263</b>	1.130 <b>4.614</b>	1.597 <b>6.521</b>	2.526 <b>10.314</b>	3.572 <b>14.586</b>	5.05 <b>20.63</b>
3	30	15	4.69	.777	.88	.851 <b>3.989</b>	1.204 <b>5.644</b>	1.702 <b>7.978</b>	2.692 <b>12.619</b>	3.806 <b>17.841</b>	5.38 <b>25.23</b>
4	32	16	5.33	.828	.91	.903 <b>4.816</b>	1.277 <b>6.811</b>	1.806 <b>9.632</b>	2.856 <b>15.232</b>	4.039 <b>21.541</b>	5.71 <b>30.46</b>
5	34	17	6.02	.880	.94	.955 <b>5.750</b>	1.350 <b>8.123</b>	1.909 <b>11.494</b>	3.019 <b>18.177</b>	4.269 <b>25.704</b>	6.04 <b>36.35</b>
6	36	18	6.75	.932	.97	1.006 <b>6.791</b>	1.422 <b>9.599</b>	2.011 <b>13.574</b>	3.180 <b>21.465</b>	4.497 <b>30.355</b>	6.36 <b>42.93</b>
7	40	20	8.33	1.036	1.02	1.106 <b>9.217</b>	1.564 <b>13.033</b>	2.212 <b>18.433</b>	3.497 <b>29.142</b>	4.946 <b>41.217</b>	6.99 <b>58.28</b>
8	44	22	10.08	1.139	1.07	1.205 <b>12.150</b>	1.703 <b>17.172</b>	2.409 <b>24.290</b>	3.809 <b>38.407</b>	5.387 <b>54.318</b>	7.62 <b>76.81</b>
9	48	24	12.00	1.243	1.12	1.301 <b>15.612</b>	1.840 <b>22.060</b>	2.602 <b>31.224</b>	4.115 <b>49.380</b>	5.819 <b>68.828</b>	8.23 <b>98.75</b>
10	52	26	14.08	1.346	1.16	1.396 <b>19.660</b>	1.974 <b>27.800</b>	2.792 <b>39.321</b>	4.415 <b>62.178</b>	6.244 <b>87.936</b>	8.83 <b>124.36</b>

TABLE XVI.—OPEN TRAPEZOIDAL CHANNELS (Con.)

## Bazin's Fourth Form

FOR UNEVEN SURFACES, LOOSE EARTH, ETC.



Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.

No.	Width feet	Depth feet	Area sq.ft.	r feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)
11	4.5	2.25	17.72	1.405	1.19	1.025 18.162	1.45 25.68	2.05 36.32	2.90 51.37	4.58 81.21	6.48 114.86
12	5.0	2.5	21.88	1.561	1.25	1.123 24.566	1.59 34.74	2.25 49.13	3.18 69.45	5.02 109.83	7.10 155.33
13	5.5	2.6	24.44	1.643	1.28	1.173 28.668	1.66 40.55	2.35 57.36	3.32 81.12	5.25 128.24	7.42 181.37
14	6.0	2.7	27.14	1.725	1.31	1.223 33.186	1.73 46.94	2.45 66.37	3.46 93.89	5.47 148.43	7.74 209.92
15	6.5	2.8	29.96	1.805	1.34	1.271 38.079	1.80 53.87	2.54 76.19	3.60 107.74	5.69 170.32	8.04 240.88
16	7.0	2.9	32.92	1.886	1.37	1.319 43.418	1.87 61.42	2.64 86.86	3.73 122.81	5.90 194.30	8.34 274.64
17	7.5	3.0	36.00	1.965	1.40	1.366 49.176	1.93 69.52	2.73 98.32	3.86 139.03	6.11 219.85	8.64 310.90
18	8.0	3.1	39.22	2.045	1.43	1.412 55.372	2.00 78.31	2.82 110.74	3.99 166.59	6.31 247.60	8.93 350.18
19	9.0	3.2	44.16	2.150	1.47	1.472 65.004	2.08 91.94	2.94 130.01	4.16 183.84	6.58 290.66	9.31 411.09
20	10.0	3.3	49.34	2.253	1.50	1.530 75.483	2.16 106.76	3.06 150.97	4.33 213.47	6.84 337.50	9.68 477.32
21	11.0	3.4	54.7	2.354	1.53	1.30 70.89	1.59 86.82	2.24 123.78	3.17 173.64	4.49 245.51	7.1 388.2
22	12.0	3.5	60.4	2.452	1.57	1.34 80.84	1.64 98.96	2.32 140.01	3.28 197.97	4.64 279.96	7.3 442.7
23	13.0	3.6	66.2	2.550	1.60	1.38 91.54	1.69 112.08	2.39 158.51	3.39 224.22	4.79 317.09	7.6 501.4
24	14.0	3.7	72.3	2.646	1.63	1.42 103.01	1.74 126.15	2.47 178.38	3.49 252.23	4.93 356.76	7.8 564.0
25	16.0	3.8	82.5	2.776	1.67	1.48 121.96	1.81 149.42	2.56 211.26	3.62 298.84	5.13 422.61	8.1 668.2
26	18.0	3.9	93.0	2.901	1.70	1.53 142.80	1.88 174.50	2.65 246.86	3.75 349.09	5.31 493.63	8.4 780.6
27	20.0	4.0	104.0	3.021	1.74	1.58 164.53	1.94 201.55	2.74 284.96	3.88 403.00	5.48 569.92	8.7 901.2
28	22.0	4.1	115.4	3.138	1.77	1.63 188.13	2.00 230.37	2.82 328.82	3.99 460.55	5.65 651.63	8.9 1030.3
29	24.0	4.2	127.3	3.251	1.80	1.68 213.29	2.05 261.14	2.90 369.31	4.10 522.28	5.80 738.62	9.2 1168.0
30	26.0	4.3	139.5	3.362	1.83	1.72 240.00	2.11 293.86	2.98 415.68	4.21 587.86	5.96 831.35	9.4 1314.4

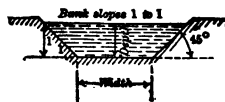
TABLE XVII.—OPEN TRAPEZOIDAL CHANNELS

## Kutter's Formula

When  $n$  equals .017.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width ins.	Depth ins.	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)
1	6	3	.188	.1553	.394	.306	.448	.644	.910	1.439	2.035
						.067	.084	.121	.171	0.270	0.382
2	8	4	.333	.2071	.455	.392	.573	.819	1.159	1.832	2.591
						.131	.191	.273	0.386	0.611	0.864
3	10	5	.521	.2589	.509	.469	.684	.977	1.382	2.186	3.091
						.244	.356	.509	0.720	1.129	1.610
4	12	6	.750	.3107	.557	.544	.792	1.131	1.599	2.529	3.576
						.408	.594	0.843	1.199	1.897	2.682
5	14	7	1.021	.3624	.602	.614	.892	1.275	1.803	2.850	4.031
						.627	.911	1.302	1.841	2.909	4.115
6	16	8	1.333	.4142	.644	.685	.993	1.417	2.004	3.169	4.481
						.913	1.324	1.839	2.672	4.225	5.975
7	18	9	1.688	.4660	.683	.751	1.086	1.549	2.190	3.463	4.898
						1.267	1.833	2.614	3.696	5.844	8.265
8	20	10	2.083	.5178	.720	.815	1.177	1.679	2.374	3.753	5.308
						1.698	2.452	3.498	4.946	7.819	11.058
9	22	11	2.521	.5695	.755	.877	1.265	1.805	2.552	4.035	5.707
						2.211	3.189	4.550	6.433	10.171	14.386
10	24	12	3.000	.6213	.788	.935	1.347	1.924	2.720	4.301	6.083
						2.805	4.041	5.772	8.160	12.903	18.249
						.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)
11	26	13	3.52	.673	.82	.797	.994	1.430	2.041	2.886	4.56
						2.806	3.500	5.035	7.186	10.161	16.07
12	28	14	4.08	.725	.85	.845	1.051	1.512	2.156	3.049	4.82
						3.450	4.292	6.174	8.804	12.450	19.68
13	30	15	4.69	.777	.88	.890	1.106	1.591	2.267	3.206	5.07
						4.172	5.184	7.458	10.627	15.023	23.76
14	32	16	5.33	.828	.91	.935	1.161	1.668	2.375	3.359	5.31
						4.987	6.192	8.896	12.667	17.915	28.33
15	34	17	6.02	.880	.94	.979	1.215	1.744	2.482	3.511	5.55
						5.895	7.316	10.501	14.944	21.140	33.42
16	36	18	6.75	.932	.97	1.021	1.267	1.817	2.586	3.657	5.78
						6.892	8.552	12.265	17.456	24.655	39.03
17	40	20	8.33	1.036	1.02	1.105	1.370	1.962	2.790	3.946	6.24
						9.208	11.417	16.350	23.250	32.883	51.99
18	44	22	10.08	1.139	1.07	1.184	1.467	2.099	2.982	4.218	6.67
						11.939	14.792	21.165	30.068	42.531	67.25
19	48	24	12.00	1.243	1.12	1.263	1.563	2.234	3.172	4.486	7.09
						15.156	18.756	26.808	38.064	53.832	85.12
20	52	26	14.08	1.346	1.16	1.338	1.655	2.362	3.353	4.741	7.50
						18.843	23.308	33.265	47.221	66.769	105.58

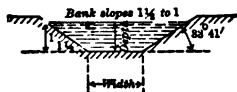
TABLE XVII.—OPEN TRAPEZOIDAL CHANNELS (Con.)

## Kutter's Formula

When  $n$  equals .017.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width feet	Depth feet	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)
21	4.5	2.25	17.72	1.405	1.19	1.180 20.908	1.380 24.452	1.71 30.23	2.43 43.11	3.45 61.18	4.88 86.54
22	5.0	2.5	21.88	1.561	1.25	1.275 27.891	1.488 32.550	1.84 40.18	2.62 57.39	3.72 81.27	5.25 114.91
23	5.5	2.6	24.44	1.643	1.28	1.325 32.333	1.544 37.735	1.91 46.56	2.72 66.38	3.85 94.09	5.45 133.08
24	6.0	2.7	27.14	1.725	1.31	1.371 37.202	1.598 43.363	1.97 53.43	2.81 76.17	3.98 107.97	5.63 152.69
25	6.5	2.8	29.96	1.805	1.34	1.419 42.513	1.652 49.494	2.04 60.97	2.90 86.82	4.11 123.08	5.81 174.07
26	7.0	2.9	32.92	1.886	1.37	1.463 48.155	1.702 56.021	2.10 68.99	2.98 98.22	4.23 139.20	5.98 196.87
27	7.5	3.0	36.00	1.965	1.40	1.507 54.252	1.753 68.108	2.16 77.69	3.07 110.48	4.35 156.60	6.15 221.47
28	8.0	3.1	39.22	2.045	1.43	1.550 60.783	1.802 70.665	2.22 86.94	3.15 123.65	4.47 175.21	6.32 247.80
29	9.0	3.2	44.16	2.150	1.47	1.606 70.921	1.866 82.403	2.29 101.30	3.26 143.96	4.62 203.98	6.53 288.50
30	10.0	3.3	49.34	2.253	1.50	1.660 81.896	1.928 95.118	2.37 116.88	3.36 165.96	4.77 235.18	6.74 332.57
31	11.0	3.4	54.7	2.354	1.53	1.53 83.53	1.71 93.72	1.99 108.77	2.44 133.62	3.46 189.62	4.91 268.61
32	12.0	3.5	60.4	2.452	1.57	1.57 94.85	1.76 106.44	2.04 123.41	2.51 151.60	3.56 215.06	5.04 304.41
33	13.0	3.6	66.2	2.550	1.60	1.62 106.98	1.81 120.03	2.10 139.04	2.58 170.83	2.66 242.17	5.17 342.73
34	14.0	3.7	72.3	2.646	1.63	1.66 119.93	1.86 134.54	2.15 155.81	2.64 191.25	3.75 271.11	5.30 383.52
35	16.0	3.8	82.5	2.776	1.67	1.72 141.42	1.92 158.49	2.23 183.47	2.73 225.03	3.87 318.87	5.47 451.06
36	18.0	3.9	93.0	2.901	1.70	1.77 164.54	1.98 184.36	2.29 213.19	2.81 261.37	3.98 370.20	5.63 523.58
37	20.0	4.0	104.0	3.021	1.74	1.82 189.38	2.04 211.95	2.36 245.02	2.89 300.25	4.09 425.15	5.78 601.22
38	22.0	4.1	115.4	3.138	1.77	1.87 215.83	2.09 241.45	2.42 278.96	2.96 341.63	4.19 483.59	5.92 683.72
39	24.0	4.2	127.3	3.251	1.80	1.92 243.96	2.14 272.85	2.48 315.22	3.03 385.73	4.29 545.82	6.06 771.58
40	26.0	4.3	139.5	3.362	1.83	1.96 273.91	2.20 306.23	2.53 353.58	3.10 432.70	4.39 612.00	6.20 864.98

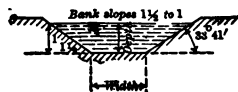
TABLE XVII.—OPEN TRAPEZOIDAL CHANNELS (Con.)

## Kutter's Formula

When  $n$  equals .017.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



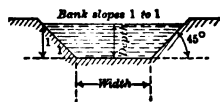
No.	Width feet	Depth feet	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.00898 (.426)	.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)
41	28.0	4.4	152.2	3.47	1.86	1.81 274.79	2.01 305.39	2.24 341.32	2.6 393.8	3.2 452.1	4.5 651.4
42	30.0	4.5	165.4	3.58	1.89	1.84 304.95	2.05 338.69	2.29 378.38	2.6 436.4	3.2 524.2	4.6 754.6
43	32.0	4.6	178.9	3.68	1.92	1.88 336.94	2.09 373.99	2.33 417.65	2.7 481.5	3.3 589.2	4.7 832.1
44	34.0	4.7	192.9	3.79	1.95	1.92 370.63	2.13 411.14	2.38 458.99	2.7 529.0	3.4 647.1	4.7 913.5
45	36.0	4.8	207.4	3.89	1.97	1.96 406.01	2.17 449.97	2.42 502.23	2.8 578.5	3.4 707.5	4.8 998.6
46	38.0	4.9	222.2	3.99	2.00	2.00 443.32	2.21 490.87	2.47 547.76	2.8 630.9	3.5 771.3	4.9 1088.4
47	40.0	5.0	237.5	4.09	2.02	2.03 482.36	2.25 533.66	2.51 595.41	2.9 685.4	3.5 837.7	5.0 1182.0
48	44.0	5.2	269.4	4.29	2.07	2.10 565.93	2.32 625.72	2.59 697.10	3.0 802.2	3.6 979.9	5.1 1382.4
49	48.0	5.4	302.9	4.49	2.12	2.17 656.77	2.40 725.54	2.67 807.64	3.1 929.1	3.7 1134.5	5.3 1599.8
50	52.0	5.6	338.2	4.69	2.17	2.24 755.97	2.47 834.10	2.75 928.47	3.2 1067.1	3.9 1302.6	5.4 1835.3
51	56.0	5.80	375.3	4.88	2.21	2.0 759.5	2.3 862.7	2.5 950.5	2.9 1057.9	3.2 1215.1	4.0 1482.7
52	60.0	6.00	414.0	5.07	2.25	2.1 860.7	2.4 977.5	2.6 1076.4	2.9 1197.3	3.3 1374.5	4.1 1676.7
53	65.0	6.25	464.8	5.31	2.30	2.1 997.1	2.4 1132.8	2.7 1246.2	3.0 1385.2	3.4 1589.8	4.2 1937.9
54	70.0	6.50	518.4	5.55	2.36	2.2 1146.6	2.5 1302.2	2.8 1431.2	3.1 1589.9	3.5 1823.6	4.3 2222.3
55	75.0	6.75	574.6	5.78	2.41	2.3 1308.4	2.6 1486.5	2.8 1631.8	3.2 1811.7	3.6 2076.6	4.4 2529.4
56	80.0	7.00	633.5	6.02	2.45	2.3 1483.0	2.7 1685.1	2.9 1847.9	3.2 2050.6	3.7 2349.7	4.5 2861.5
57	85.0	7.25	695.1	6.25	2.50	2.4 1670.3	2.7 1897.6	3.0 2079.7	3.3 2305.6	3.8 2641.4	4.6 3216.2
58	90.0	7.50	759.4	6.49	2.55	2.5 1871.1	2.8 2124.7	3.1 2326.7	3.4 2578.9	3.9 2953.2	4.7 3594.1
59	95.0	7.75	826.3	6.72	2.59	2.5 2085.7	2.9 2369.1	3.1 2592.2	3.5 2872.4	4.0 3287.2	4.8 3998.7
60	100.0	8.00	896.0	6.95	2.64	2.6 2313.5	2.9 2628.0	3.2 2873.5	3.6 3182.6	4.1 3641.3	4.9 4428.9

TABLE XVIII.—OPEN TRAPEZOIDAL CHANNELS

**Kutter's Formula**When  $n$  equals .020.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width ins.	Depth ins.	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)
1	6	3	.188	.1553	.394	.359 <b>.067</b>	.517 <b>.097</b>	.731 <b>.137</b>	1.16 <b>0.22</b>	1.64 <b>0.31</b>	2.31 <b>0.43</b>
2	8	4	.333	.2071	.455	.461 <b>.184</b>	.662 <b>.221</b>	.936 <b>.312</b>	1.48 <b>0.49</b>	2.09 <b>0.70</b>	2.96 <b>0.99</b>
3	10	5	.521	.2589	.509	.553 <b>.283</b>	.792 <b>.413</b>	1.120 <b>0.583</b>	1.77 <b>0.92</b>	2.51 <b>1.31</b>	3.54 <b>1.85</b>
4	12	6	.750	.3107	.557	.642 <b>.482</b>	.918 <b>.689</b>	1.298 <b>0.974</b>	2.05 <b>1.54</b>	2.90 <b>2.18</b>	4.11 <b>3.08</b>
5	14	7	1.021	.3624	.602	.726 <b>.741</b>	1.037 <b>1.059</b>	1.466 <b>1.496</b>	2.32 <b>2.37</b>	3.28 <b>3.35</b>	4.64 <b>4.73</b>
6	16	8	1.333	.4142	.644	.811 <b>1.081</b>	1.156 <b>1.541</b>	1.635 <b>2.180</b>	2.59 <b>3.45</b>	3.66 <b>4.83</b>	5.17 <b>6.89</b>
7	18	9	1.688	.4660	.683	.889 <b>1.500</b>	1.267 <b>2.133</b>	1.792 <b>3.024</b>	2.83 <b>4.78</b>	4.01 <b>6.76</b>	5.67 <b>9.56</b>
8	20	10	2.083	.5172	.720	.966 <b>2.012</b>	1.376 <b>2.867</b>	1.946 <b>4.054</b>	3.08 <b>6.41</b>	4.35 <b>9.07</b>	6.16 <b>12.82</b>
9	22	11	2.521	.5695	.755	1.039 <b>2.619</b>	1.482 <b>3.736</b>	2.097 <b>5.286</b>	3.32 <b>8.36</b>	4.69 <b>11.82</b>	6.63 <b>16.71</b>
10	24	12	3.000	.6213	.788	1.108 <b>3.324</b>	1.583 <b>4.749</b>	2.238 <b>6.714</b>	3.54 <b>10.62</b>	5.01 <b>15.02</b>	7.08 <b>21.23</b>
11	26	13	3.52	.673	.82	.82 <b>2.83</b>	1.18 <b>4.15</b>	1.68 <b>5.92</b>	2.38 <b>8.38</b>	3.76 <b>13.25</b>	5.32 <b>18.73</b>
12	28	14	4.08	.725	.85	.87 <b>3.54</b>	1.25 <b>5.10</b>	1.78 <b>7.27</b>	2.52 <b>10.28</b>	3.98 <b>16.26</b>	5.63 <b>22.99</b>
13	30	15	4.69	.777	.88	.91 <b>4.28</b>	1.32 <b>6.16</b>	1.88 <b>8.79</b>	2.65 <b>12.43</b>	4.19 <b>19.66</b>	5.93 <b>27.80</b>
14	32	16	5.33	.828	.91	.96 <b>5.12</b>	1.38 <b>7.36</b>	1.97 <b>10.50</b>	2.78 <b>14.84</b>	4.40 <b>23.47</b>	6.22 <b>33.19</b>
15	34	17	6.02	.880	.94	1.01 <b>6.06</b>	1.45 <b>8.70</b>	2.06 <b>12.40</b>	2.91 <b>17.53</b>	4.60 <b>27.72</b>	6.51 <b>39.20</b>
16	36	18	6.75	.932	.97	1.05 <b>7.09</b>	1.51 <b>10.17</b>	2.15 <b>14.49</b>	3.04 <b>20.50</b>	4.80 <b>32.41</b>	6.79 <b>45.83</b>
17	40	20	8.33	1.036	1.02	1.14 <b>9.49</b>	1.63 <b>13.59</b>	2.32 <b>19.35</b>	3.28 <b>27.37</b>	5.19 <b>43.28</b>	7.34 <b>61.20</b>
18	44	22	10.08	1.139	1.07	1.22 <b>12.32</b>	1.75 <b>17.63</b>	2.49 <b>25.11</b>	3.52 <b>35.50</b>	5.57 <b>56.14</b>	7.87 <b>79.40</b>
19	48	24	12.00	1.243	1.12	1.30 <b>15.65</b>	1.86 <b>22.37</b>	2.65 <b>31.85</b>	3.75 <b>45.04</b>	5.93 <b>71.21</b>	8.39 <b>100.70</b>
20	52	26	14.08	1.346	1.16	1.38 <b>19.46</b>	1.98 <b>27.82</b>	2.81 <b>39.53</b>	3.97 <b>55.91</b>	6.28 <b>88.42</b>	8.88 <b>125.03</b>

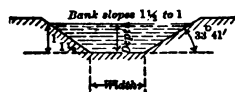
TABLE XVIII.—OPEN TRAPEZOIDAL CHANNELS (Con.)

## Kutter's Formula

When  $n$  equals .020.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width feet	Depth feet	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)
21	4.5	2.25	17.72	1.405	1.19	1.153 20.420	1.425 25.250	2.04 36.08	2.89 51.26	4.09 72.49	6.47 114.62
22	5.0	2.5	21.88	1.561	1.25	1.247 27.278	1.539 33.666	2.20 43.04	3.12 58.21	4.41 76.45	6.97 152.49
23	5.5	2.6	24.44	1.643	1.28	1.296 31.674	1.598 39.055	2.28 55.67	3.23 79.04	4.57 111.79	7.23 176.75
24	6.0	2.7	27.14	1.725	1.31	1.341 36.388	1.654 44.881	2.36 63.93	3.35 90.77	4.73 128.35	7.48 202.94
25	6.5	2.8	29.96	1.805	1.34	1.388 41.584	1.711 51.262	2.44 72.98	3.46 103.61	4.89 146.42	7.73 231.47
26	7.0	2.9	32.92	1.886	1.37	1.431 47.101	1.764 58.062	2.51 82.58	3.56 117.14	5.03 165.66	7.96 261.94
27	7.5	3.0	36.00	1.965	1.40	1.475 53.100	1.817 65.412	2.58 92.99	3.66 131.87	5.18 186.48	8.19 294.84
28	8.0	3.1	39.22	2.045	1.43	1.518 59.528	1.869 73.293	2.66 104.16	3.77 147.68	5.33 208.82	8.42 330.19
29	9.0	3.2	44.16	2.150	1.47	1.573 69.464	1.936 85.494	2.75 121.44	3.90 172.14	5.51 243.41	8.72 384.90
30	10.0	3.3	49.34	2.253	1.50	1.627 80.268	2.000 98.670	2.84 140.11	4.03 198.62	5.69 280.91	9.00 444.16
31	11.0	3.4	54.7	2.354	1.53	1.45 79.15	1.68 91.85	2.06 112.93	2.93 160.39	4.15 227.06	5.9 321.2
32	12.0	3.5	60.4	2.452	1.57	1.49 90.02	1.73 104.39	2.12 128.15	3.02 182.09	4.27 257.62	6.0 364.3
33	13.0	3.6	66.2	2.550	1.60	1.53 101.55	1.78 117.71	2.18 144.47	3.10 205.34	4.38 290.20	6.2 410.4
34	14.0	3.7	72.3	2.646	1.63	1.58 113.93	1.82 131.94	2.24 161.89	3.17 229.52	4.49 324.92	6.4 459.5
35	16.0	3.8	82.5	2.776	1.67	1.63 134.33	1.89 155.52	2.31 190.73	3.28 270.22	4.64 382.37	6.6 540.7
36	18.0	3.9	93.0	2.901	1.70	1.68 156.27	1.94 180.82	2.38 221.75	3.38 314.02	4.77 444.05	6.8 627.9
37	20.0	4.0	104.0	3.021	1.74	1.73 179.92	2.00 208.00	2.45 255.01	3.47 360.88	4.91 510.43	6.9 721.9
38	22.0	4.1	115.4	3.138	1.77	1.78 205.09	2.05 236.95	2.52 290.35	3.56 410.88	5.03 581.00	7.2 821.6
39	24.0	4.2	127.3	3.251	1.80	1.82 231.87	2.10 267.76	2.58 323.08	3.65 463.99	5.16 556.15	7.3 928.0
40	26.0	4.3	139.5	3.362	1.83	1.87 260.51	2.15 300.56	2.64 368.09	3.73 520.47	5.28 736.05	7.5 1040.9

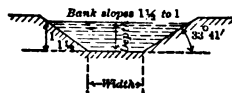
TABLE XVIII.—OPEN TRAPEZOIDAL CHANNELS (Con.)

### Kutter's Formula

**When  $n$  equals .020.**

**Light type, the mean velocity in ft. per sec.**

**Heavy type, the discharge in cu.ft. per sec.**



No.	Width feet	Depth feet	Area sq. ft.	r feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)
41	28.0	4.4	152.2	3.47	1.86	1.71 260.03	1.91 290.47	2.20 338.23	2.7 410.4	3.8 579.9	5.4 820.0
42	30.0	4.5	165.4	3.58	1.89	1.74 288.41	1.95 322.15	2.25 371.60	2.8 454.9	3.9 542.3	5.5 808.4
43	32.0	4.6	178.9	3.68	1.92	1.78 318.69	1.99 355.91	2.29 410.81	2.8 502.1	4.0 708.8	5.6 1002.2
44	34.0	4.7	192.9	3.79	1.95	1.82 350.56	2.03 391.27	2.34 450.89	2.9 551.6	4.0 778.5	5.7 1100.7
45	36.0	4.8	207.4	3.89	1.97	1.85 384.03	2.07 428.41	2.38 493.52	2.9 603.4	4.1 851.6	5.8 1203.7
46	38.0	4.9	222.2	3.99	2.00	1.89 419.10	2.10 467.32	2.42 538.43	3.0 658.0	4.2 928.4	5.9 1312.4
47	40.0	5.0	237.5	4.09	2.02	1.92 456.00	2.14 508.25	2.46 585.30	3.0 714.9	4.3 1008.7	6.0 1428.2
48	44.0	5.2	269.4	4.29	2.07	1.99 534.68	2.21 595.82	2.55 685.52	3.1 837.2	4.4 1180.3	6.2 1667.1
49	48.0	5.4	302.9	4.49	2.12	2.05 620.42	2.28 691.01	2.62 794.61	3.2 970.0	4.5 1366.9	6.4 1929.7
50	52.0	5.6	338.2	4.69	2.17	2.11 713.69	2.35 794.53	2.70 912.91	3.3 1114.2	4.6 1569.1	6.5 2215.1
						.00898 (.426)	.01000 (.528)	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)
51	56.0	5.80	375.3	4.88	2.21	2.0 738.9	2.2 814.3	2.4 905.9	2.8 1040.6	3.4 1269.5	4.8 1787.0
52	60.0	6.00	414.0	5.07	2.25	2.0 837.9	2.2 922.8	2.5 1025.9	2.8 1177.8	3.5 1436.6	4.9 2022.0
53	65.0	6.25	464.8	5.31	2.30	2.1 972.0	2.3 1069.6	2.6 1188.1	2.9 1362.9	3.6 1661.8	5.0 2338.6
54	70.0	6.50	518.4	5.55	2.36	2.2 1118.7	2.4 1229.1	2.6 1364.9	3.0 1564.5	3.7 1906.1	5.2 2681.6
55	75.0	6.75	574.6	5.78	2.41	2.2 1277.3	2.4 1402.0	2.7 1556.6	3.1 1783.0	3.8 2170.8	5.3 3052.2
56	80.0	7.00	633.5	6.02	2.45	2.3 1449.4	2.5 1588.8	2.8 1763.0	3.2 2019.0	3.9 2457.3	5.5 3453.8
57	85.0	7.25	695.1	6.25	2.50	2.4 1633.5	2.6 1788.5	2.9 1983.8	3.3 2270.9	4.0 2763.0	5.6 3882.8
58	90.0	7.50	759.4	6.49	2.55	2.4 1830.9	2.6 2003.2	2.9 2220.4	3.3 2540.9	4.1 3090.7	5.7 4341.3
59	95.0	7.75	826.3	6.72	2.59	2.5 2043.6	2.7 2232.8	3.0 2474.1	3.4 2830.2	4.2 3440.9	5.8 4832.5
60	100.0	8.00	896.0	6.95	2.64	2.5 2267.8	2.8 2476.5	3.1 2743.6	3.5 3136.0	4.3 3812.5	6.0 5351.8

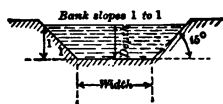
TABLE XIX.—OPEN TRAPEZOIDAL CHANNELS

## Kutter's Formula

When  $n$  equals .025.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width ins.	Depth ins.	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)	.22361 (264)
1	6	3	.188	.1553	.394	.381 .071	.539 .101	.852 .160	1.21 0.33	1.70 0.32	2.69 0.51
2	8	4	.333	.2071	.455	.493 .164	.697 .232	1.102 0.867	1.56 0.52	2.21 0.74	3.49 1.16
3	10	5	.521	.2589	.509	.594 .309	.840 .438	1.328 0.692	1.88 0.98	2.66 1.38	4.20 2.19
4	12	6	.750	.3107	.557	.691 .518	.977 .733	1.545 1.159	2.19 1.64	3.09 2.32	4.89 3.67
5	14	7	1.021	.3624	.602	.782 .798	1.106 1.129	1.749 1.785	2.47 2.53	3.50 3.57	5.53 5.65
6	16	8	1.333	.4142	.644	.875 1.167	1.238 1.651	1.957 2.609	2.77 3.69	3.92 5.22	6.19 8.25
7	18	9	1.688	.4660	.683	.962 1.623	1.360 2.295	2.150 3.628	3.04 5.13	4.30 7.26	6.80 11.48
8	20	10	2.083	.5178	.720	1.047 2.181	1.480 3.083	2.341 4.877	3.31 6.90	4.68 9.75	7.40 15.42
9	22	11	2.521	.5695	.755	1.130 2.849	1.598 4.028	2.526 6.368	3.57 9.01	5.05 12.74	7.99 20.14
10	24	12	3.000	.6213	.788	1.208 3.624	1.708 5.124	2.701 8.103	3.82 11.46	5.40 16.21	8.54 25.63
<hr/>											
	ins.	ins.	sq.ft.	feet	feet	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)
11	26	13	3.52	.673	.82	.90 3.18	1.29 4.53	1.82 6.41	2.88 10.13	4.07 14.33	5.76 20.27
12	28	14	4.08	.725	.85	.96 3.91	1.37 5.57	1.93 7.89	3.05 12.47	4.32 17.63	6.11 24.94
13	30	15	4.69	.777	.88	1.01 4.74	1.44 6.76	2.04 9.55	3.22 15.11	4.56 21.37	6.45 30.22
14	32	16	5.33	.828	.91	1.06 5.67	1.52 8.09	2.14 11.43	3.39 18.08	4.79 25.56	6.78 36.15
15	34	17	6.02	.880	.94	1.12 6.71	1.59 9.57	2.25 13.53	3.55 21.39	5.03 30.26	7.11 42.79
16	36	18	6.75	.932	.97	1.17 7.86	1.66 11.21	2.35 15.85	3.71 25.06	5.25 35.44	7.43 50.12
17	40	20	8.33	1.036	1.02	1.27 10.54	1.80 15.01	2.55 21.22	4.03 33.56	5.70 47.46	8.05 67.12
18	44	22	10.08	1.139	1.07	1.36 13.71	1.93 19.50	2.74 27.58	4.33 43.61	6.12 61.67	8.65 87.21
19	48	24	12.00	1.243	1.12	1.45 17.45	2.07 24.79	2.92 35.05	4.62 55.43	6.53 78.38	9.24 110.86
20	52	26	14.08	1.346	1.16	1.54 21.72	2.19 30.86	3.10 43.63	4.90 68.99	6.93 97.57	9.80 137.99

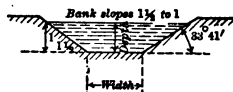
TABLE XIX.—OPEN TRAPEZOIDAL CHANNELS (Con.)

## Kutter's Formula

When  $n$  equals .025.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width feet	Depth feet	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)
21	4.5	2.25	17.72	1.405	1.19	1.12 19.76	1.59 28.21	2.26 40.05	3.20 56.65	5.05 89.55	7.15 126.66
22	5.0	2.5	21.88	1.561	1.25	1.21 26.40	1.72 37.65	2.44 53.44	3.46 75.58	5.46 119.50	7.73 169.01
23	5.5	2.6	24.44	1.643	1.28	1.26 30.67	1.79 43.70	2.54 62.03	3.59 87.72	5.68 138.70	8.03 196.16
24	6.0	2.7	27.14	1.725	1.31	1.30 35.28	1.85 50.25	2.63 71.34	3.72 100.86	5.88 159.47	8.31 225.55
25	6.5	2.8	29.96	1.805	1.34	1.35 40.33	1.92 57.43	2.72 81.52	3.85 118.29	6.08 182.28	8.60 257.78
26	7.0	2.9	32.92	1.886	1.37	1.39 45.72	1.98 65.11	2.81 92.39	3.97 130.64	6.28 206.58	8.88 292.15
27	7.5	3.0	36.00	1.965	1.40	1.43 51.55	2.04 73.40	2.89 104.15	4.09 147.31	6.47 232.88	9.15 329.36
28	8.0	3.1	39.22	2.045	1.43	1.48 57.84	2.10 82.31	2.98 116.74	4.21 165.10	6.66 261.05	9.42 369.21
29	9.0	3.2	44.16	2.150	1.47	1.53 67.61	2.18 96.05	3.09 136.23	4.36 192.67	6.90 304.66	9.76 430.87
30	10.0	3.3	49.34	2.253	1.50	1.58 78.15	2.25 111.00	3.19 157.43	4.51 222.60	7.14 352.01	10.09 497.79
31	11.0	3.4	54.7	2.354	1.53	1.33 72.86	1.64 89.50	2.32 127.05	3.29 180.15	4.65 254.76	7.4 402.8
32	12.0	3.5	60.4	2.452	1.57	1.37 82.84	1.69 101.73	2.39 144.30	3.39 204.55	4.79 289.26	7.6 457.4
33	13.0	3.6	66.2	2.550	1.60	1.41 93.47	1.73 114.79	2.46 162.82	3.48 230.65	4.92 326.17	7.8 515.8
34	14.0	3.7	72.3	2.646	1.63	1.45 104.89	1.78 128.76	2.52 182.50	3.58 258.60	5.06 365.73	8.0 578.3
35	16.0	3.8	82.5	2.776	1.67	1.50 123.77	1.84 151.89	2.61 215.14	3.70 304.77	5.23 431.02	8.3 681.5
36	18.0	3.9	93.0	2.901	1.70	1.55 144.08	1.90 176.82	2.69 250.21	3.81 354.49	5.39 501.26	8.5 792.6
37	20.0	4.0	104.0	3.021	1.74	1.60 165.98	1.96 203.53	2.77 287.98	3.92 407.68	5.54 576.58	8.8 911.6
38	22.0	4.1	115.4	3.138	1.77	1.64 189.40	2.01 231.98	2.84 328.24	4.02 464.32	5.69 656.71	9.0 1038.3
39	24.0	4.2	127.3	3.251	1.80	1.68 214.31	2.06 262.41	2.92 371.09	4.12 524.82	5.83 742.18	9.2 1173.5
40	26.0	4.3	139.5	3.362	1.83	1.73 240.70	2.11 294.70	2.99 416.65	4.22 589.26	5.97 833.30	9.4 1317.5

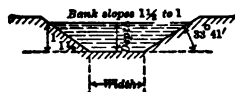
TABLE XIX.—OPEN TRAPEZOIDAL CHANNELS (Con.)

## Kutter's Formula

When  $n$  equals .025.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width feet	Depth feet	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)
41	28.0	4.4	152.2	3.47	1.86	1.53	1.76	2.16	3.1	4.3	6.1
42	30.0	4.5	165.4	3.58	1.89	1.56	1.80	2.21	3.1	4.4	6.2
43	32.0	4.6	178.9	3.68	1.92	1.60	1.84	2.25	3.2	4.5	6.4
44	34.0	4.7	192.9	3.79	1.95	1.63	1.88	2.30	3.2	4.6	6.5
45	36.0	4.8	207.4	3.89	1.97	1.66	1.91	2.34	3.3	4.7	6.6
46	38.0	4.9	222.2	3.99	2.00	1.69	1.95	2.38	3.4	4.7	6.7
47	40.0	5.0	237.5	4.09	2.02	1.72	1.98	2.42	3.4	4.8	6.8
48	44.0	5.2	269.4	4.29	2.07	1.78	2.05	2.50	3.5	5.0	7.0
49	48.0	5.4	302.9	4.49	2.12	1.84	2.12	2.58	3.6	5.1	7.3
50	52.0	5.6	338.2	4.69	2.17	1.90	2.18	2.66	3.7	5.3	7.5
51	56.0	5.80	375.3	4.88	2.21	1.8	2.0	2.2	2.7	3.8	5.4
52	60.0	6.00	414.0	5.07	2.25	1.8	2.0	2.3	2.8	4.0	5.6
53	65.0	6.25	464.8	5.31	2.30	1.9	2.1	2.4	2.9	4.1	5.7
54	70.0	6.50	518.4	5.55	2.36	1.9	2.1	2.4	3.0	4.2	5.9
55	75.0	6.75	574.6	5.78	2.41	2.0	2.2	2.5	3.1	4.3	6.1
56	80.0	7.00	633.5	6.02	2.45	2.0	2.3	2.6	3.2	4.4	6.2
57	85.0	7.25	695.1	6.25	2.50	2.1	2.3	2.7	3.2	4.5	6.4
58	90.0	7.50	759.4	6.49	2.55	2.2	2.4	2.7	3.3	4.7	6.6
59	95.0	7.75	826.3	6.72	2.59	2.2	2.4	2.8	3.4	4.8	6.7
60	100.0	8.00	896.0	6.95	2.64	2.3	2.5	2.9	3.5	4.9	6.9
						2022.8	2240.9	2559.0	3107.3	4360.8	6144.8

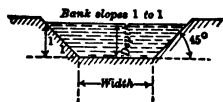
TABLE XX.—OPEN TRAPEZOIDAL CHANNELS

## Kutter's Formula

When  $n$  equals .030.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width ins.	Depth ins.	Area sq. ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)	.22361 (264)	.31623 (528)
1	6	3	.188	.1553	.394	.421 0.079	.666 1.125	.942 1.177	1.332 0.250	2.106 0.395	2.979 0.559
2	8	4	.333	.2071	.455	.547 1.182	.865 2.258	1.223 0.408	1.730 0.577	2.735 0.912	3.867 1.289
3	10	5	.521	.2589	.509	.661 1.344	1.044 0.844	1.477 0.769	2.089 1.088	3.303 1.721	4.671 2.433
4	12	6	.750	.3107	.557	.772 1.579	1.221 0.916	1.726 1.295	2.441 1.831	3.859 2.894	5.458 4.094
5	14	7	1.021	.3624	.602	.877 1.895	1.387 1.416	1.962 2.003	2.775 2.833	4.387 4.478	6.204 6.333
6	16	8	1.333	.4142	.644	.986 1.315	1.559 2.079	2.205 2.940	3.118 4.157	4.931 6.575	6.973 9.297
7	18	9	1.688	.4660	.683	1.087 1.834	1.719 2.901	2.431 4.102	3.438 5.802	5.436 9.173	7.688 12.974
8	20	10	2.083	.5178	.720	1.186 2.471	1.875 3.906	2.652 5.535	3.751 7.814	5.930 12.354	8.386 17.471
9	22	11	2.521	.5695	.755	1.282 3.232	2.027 5.110	2.866 7.235	4.053 10.217	6.409 16.156	9.063 22.846
10	24	12	3.000	.6213	.788	1.372 4.116	2.169 6.507	3.067 9.201	4.337 13.011	6.858 20.574	9.699 29.097
11	26	13	3.52	.673	.82	1.035 3.644	1.463 5.151	2.314 8.147	3.272 11.520	4.63 16.29	7.32 25.76
12	28	14	4.08	.725	.85	1.100 4.492	1.555 6.350	2.459 10.041	3.477 14.198	4.92 20.08	7.78 31.75
13	30	15	4.69	.777	.88	1.162 5.447	1.643 7.702	2.599 12.183	3.675 17.227	5.20 24.36	8.22 38.52
14	32	16	5.33	.828	.91	1.223 6.533	1.730 9.227	2.736 14.592	3.869 20.635	5.47 29.18	8.65 46.14
15	34	17	6.02	.880	.94	1.285 7.737	1.817 10.940	2.872 17.292	4.062 24.457	5.75 34.59	9.08 54.69
16	36	18	6.75	.932	.97	1.344 9.072	1.900 12.825	3.004 20.277	4.249 28.681	6.01 40.56	9.50 64.13
17	40	20	8.33	1.036	1.02	1.461 12.175	2.066 17.217	3.267 27.225	4.620 38.500	6.53 54.45	10.33 86.09
18	44	22	10.08	1.139	1.07	1.572 15.551	2.224 22.425	3.516 35.453	4.972 50.134	7.03 70.90	11.12 112.11
19	48	24	12.00	1.243	1.12	1.683 20.196	2.381 28.572	3.764 45.168	5.323 63.876	7.53 90.34	11.90 142.34
20	52	26	14.08	1.346	1.16	1.790 25.209	2.531 35.645	4.002 56.361	5.660 79.711	8.00 112.72	12.66 178.24

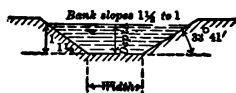
TABLE XX.—OPEN TRAPEZOIDAL CHANNELS (Con.)

## Kutter's Formula

When  $n$  equals .030.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.



No.	Width feet	Depth feet	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.02236 (2.64)	.03162 (5.26)	.04472 (10.6)	.07071 (26.4)	.10000 (52.8)	.14142 (106)
21	4.5	2.25	17.72	1.405	1.19	1.30 23.05	1.85 32.76	2.62 46.34	4.14 73.27	5.85 103.62	8.27 146.54
22	5.0	2.5	21.88	1.561	1.25	1.41 30.87	2.00 43.84	2.83 61.99	4.48 98.02	6.34 138.62	8.96 196.04
23	5.5	2.6	24.44	1.643	1.28	1.47 35.90	2.08 50.93	2.95 72.05	4.66 113.89	6.59 161.08	9.32 227.81
24	6.0	2.7	27.14	1.725	1.31	1.52 41.33	2.16 58.64	3.06 82.93	4.83 131.12	6.83 185.41	9.66 262.21
25	6.5	2.8	29.96	1.805	1.34	1.58 47.25	2.24 67.05	3.17 94.82	5.01 149.95	7.08 212.06	10.01 299.90
26	7.0	2.9	32.92	1.886	1.37	1.63 53.59	2.31 76.07	3.27 107.57	5.17 170.07	7.31 240.51	10.33 340.14
27	7.5	3.0	36.00	1.965	1.40	1.68 60.41	2.38 85.79	3.37 121.32	5.33 191.84	7.54 271.30	10.66 383.63
28	8.0	3.1	39.22	2.045	1.43	1.73 67.84	2.46 96.27	3.47 135.15	5.49 215.25	7.76 304.43	10.98 430.54
29	9.0	3.2	44.16	2.150	1.47	1.80 79.31	2.55 112.48	3.60 159.06	5.70 251.54	8.06 355.71	11.39 503.03
30	10.0	3.3	49.34	2.253	1.50	1.86 91.76	2.64 130.10	3.73 183.97	5.90 290.83	8.34 411.36	11.79 581.76
31	11.0	3.4	54.7	2.354	1.53	1.35 74.01	1.92 105.16	2.72 149.00	3.85 210.75	6.1 333.2	8.6 471.3
32	12.0	3.5	60.4	2.452	1.57	1.39 84.16	1.98 119.60	2.81 169.35	3.97 239.51	6.3 378.7	8.9 535.6
33	13.0	3.6	66.2	2.550	1.60	1.44 95.05	2.04 135.00	2.89 191.17	4.08 270.33	6.5 427.4	9.1 604.4
34	14.0	3.7	72.3	2.646	1.63	1.48 106.69	2.10 151.54	2.96 214.40	4.19 303.23	6.6 479.4	9.4 678.1
35	16.0	3.8	82.5	2.776	1.67	1.53 126.08	2.17 178.77	3.07 252.91	4.34 357.63	6.9 565.4	9.7 799.7
36	18.0	3.9	93.0	2.901	1.70	1.58 146.87	2.24 208.08	3.16 294.30	4.48 416.24	7.1 558.1	10.0 930.7
37	20.0	4.0	104.0	3.021	1.74	1.63 169.31	2.31 239.72	3.26 338.94	4.61 479.34	7.3 758.0	10.3 1071.9
38	22.0	4.1	115.4	3.138	1.77	1.67 193.21	2.37 273.30	3.35 386.53	4.74 546.61	7.5 864.3	10.6 1222.4
39	24.0	4.2	127.3	3.251	1.80	1.72 218.63	2.43 309.24	3.44 437.27	4.86 618.36	7.7 977.7	10.9 1332.8
40	26.0	4.3	139.5	3.362	1.83	1.76 245.72	2.49 347.30	3.52 491.16	4.98 694.61	7.9 1098.3	11.1 1553.3

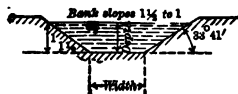
TABLE XX.—OPEN TRAPEZOIDAL CHANNELS (Con.)

## Kutter's Formula

When  $n$  equals .030.

Light type, the mean velocity in ft. per sec.

Heavy type, the discharge in cu.ft. per sec.

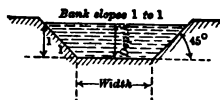


No.	Width feet	Depth feet	Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
						.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)
41	28.0	4.4	152.2	3.47	1.86	1.47	1.80	2.5	3.6	5.1	8.0
42	30.0	4.5	165.4	3.58	1.89	224.25	274.34	387.5	547.9	774.9	1225.2
43	32.0	4.6	178.9	3.68	1.92	1.51	1.84	2.6	3.7	5.2	8.2
44	34.0	4.7	192.9	3.79	1.95	248.89	304.46	429.8	607.9	859.6	1359.2
45	36.0	4.8	207.4	3.89	1.97	1.54	1.88	2.7	3.8	5.3	8.4
46	38.0	4.9	222.2	3.99	2.00	275.21	336.41	474.9	671.6	949.6	1501.5
47	40.0	5.0	237.5	4.09	2.02	1.57	1.92	2.7	3.8	5.4	8.6
48	44.0	5.2	269.4	4.29	2.07	302.72	370.24	522.3	738.6	1044.4	1651.3
49	48.0	5.4	302.9	4.49	2.12	1.60	1.96	2.8	3.9	5.5	8.7
50	52.0	5.6	338.2	4.69	2.17	331.57	405.60	571.9	808.7	1143.8	1808.4
51	56.0	5.80	375.3	4.88	2.21	1.63	1.99	2.8	4.0	5.6	8.9
52	60.0	6.00	414.0	5.07	2.25	362.21	442.87	624.2	882.6	1248.4	1973.9
53	65.0	6.25	464.8	5.31	2.30	1.66	2.03	2.9	4.0	5.7	9.0
54	70.0	6.50	518.4	5.55	2.36	394.01	481.65	679.0	960.0	1357.6	2146.5
55	75.0	6.75	574.6	5.78	2.41	1.72	2.10	3.0	4.2	5.9	9.3
56	80.0	7.00	633.5	6.02	2.45	462.76	565.12	796.8	1125.7	1591.6	2516.9
57	85.0	7.25	695.1	6.25	2.50	1.78	2.17	3.1	4.3	6.1	9.6
58	90.0	7.50	759.4	6.49	2.55	537.72	656.17	924.9	1305.7	1846.4	2919.4
59	95.0	7.75	826.3	6.72	2.59	1.83	2.23	3.1	4.4	6.3	9.9
60	100.0	8.00	896.0	6.95	2.64	619.66	755.29	1064.4	1503.1	2125.5	3360.8
51	56.0	5.80	375.3	4.88	2.21	.01118 (.66)	.01291 (.88)	.01581 (1.32)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)
52	60.0	6.00	414.0	5.07	2.25	1.6	1.9	2.3	3.2	4.6	6.5
53	65.0	6.25	464.8	5.31	2.30	616.6	707.7	862.3	1214.3	1714.6	2424.9
54	70.0	6.50	518.4	5.55	2.36	1.7	1.9	2.4	3.3	4.7	6.6
55	75.0	6.75	574.6	5.78	2.41	699.2	802.3	977.9	1376.1	1941.2	2745.2
56	80.0	7.00	633.5	6.02	2.45	1.7	2.0	2.4	3.4	4.8	6.8
57	85.0	7.25	695.1	6.25	2.50	811.2	930.2	1133.8	1594.4	2247.1	3177.7
58	90.0	7.50	759.4	6.49	2.55	1.8	2.1	2.5	3.5	5.0	7.0
59	95.0	7.75	826.3	6.72	2.59	934.1	1069.9	1303.2	1833.5	2583.6	3654.0
60	100.0	8.00	896.0	6.95	2.64	1.9	2.1	2.6	3.6	5.1	7.3
						1067.0	1221.6	1487.0	2092.7	2952.9	4169.3
56	80.0	7.00	633.5	6.02	2.45	1.9	2.2	2.7	3.7	5.3	7.5
57	85.0	7.25	695.1	6.25	2.50	1211.9	1386.1	1686.4	2369.9	3338.5	4721.5
58	90.0	7.50	759.4	6.49	2.55	2.0	2.2	2.7	3.8	5.4	7.6
59	95.0	7.75	826.3	6.72	2.59	1367.3	1562.6	1900.4	2667.1	3756.3	5311.9
60	100.0	8.00	896.0	6.95	2.64	2.0	2.3	2.8	3.9	5.5	7.8
						1533.2	1751.1	2128.5	2985.9	4207.7	5950.5
						2.1	2.4	2.9	4.0	5.7	8.0
						1710.5	1953.5	2373.3	3326.9	4692.0	6634.7
						2.1	2.4	2.9	4.1	5.8	8.2
						1899.5	2168.3	2633.3	3689.7	5203.1	7358.8

TABLE XXI.—KUTTER'S FORMULA

FOR OPEN TRAPEZOIDAL CHANNELS AND  
CANALS IN LOOSE EARTH

The bank slopes are indicated in the figure.  
The dimensions given are bottom width and  
depth of water.



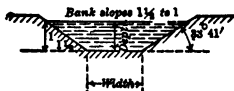
Quantity or Vol. of the Flow.	Width ins.	Depth ins.	$\sqrt{r}$ feet	Area sq.ft.	Mean Velocity Feet per Sec.	Grade, or Fall in Feet per Mile when			Z
						n = .020	n = .025	n = .030	
1.25	6	3	.394	.188	6.67	879.0	1618.0	2647.0	1
sec.-ft.	8	4	.455	.333	3.75	169.0	306.0	496.0	2
or	10	5	.508	.521	2.40	48.8	86.9	140.0	3
50	12	6	.557	.750	1.67	17.5	30.8	49.4	4
inches	16	8	.644	1.333	0.94	3.54	6.07	9.61	5
1.75	8	4	.455	.333	5.25	332.0	599.0	973.0	6
sec.-ft.	10	5	.508	.521	3.36	95.7	170.0	275.0	7
or	12	6	.557	.750	2.33	33.9	60.0	96.2	8
70	16	8	.644	1.333	1.31	6.76	11.8	18.6	9
inches	20	10	.720	2.083	0.84	2.00	3.38	5.28	10
2.50	10	5	.508	.521	4.80	195.0	348.0	561.0	11
sec.-ft.	12	6	.557	.750	3.33	69.5	123.0	197.0	12
or	16	8	.644	1.333	1.88	13.9	24.3	38.4	13
100	20	10	.720	2.083	1.20	4.01	6.92	10.8	14
inches	24	12	.788	3.000	0.83	1.53	2.53	3.85	15
3.75	12	6	.557	.750	5.00	157.0	276.0	443.0	16
sec.-ft.	16	8	.644	1.333	2.81	31.2	54.4	85.7	17
or	20	10	.720	2.083	1.80	9.03	15.6	24.3	18
150	24	12	.788	3.000	1.25	3.38	5.65	8.76	19
inches	30	15	.881	4.688	0.80	1.06	1.69	2.59	20
5.0	14	7	.602	1.021	4.90	118.0	207.0	329.0	21
sec.-ft.	18	9	.683	1.688	2.96	28.8	50.0	78.3	22
or	24	12	.788	3.000	1.67	5.88	10.1	15.7	23
200	30	15	.881	4.688	1.07	1.81	2.96	4.48	24
inches	36	18	.966	6.750	0.74	0.70	1.12	1.67	25
7.5	16	8	.644	1.333	5.63	125.0	218.0	344.0	26
sec.-ft.	20	10	.720	2.083	3.60	36.1	62.5	97.3	27
or	24	12	.788	3.000	2.50	13.2	22.6	35.1	28
300	36	18	.966	6.750	1.11	1.47	2.39	3.60	29
inches	44	22	1.067	10.083	0.74	0.53	0.84	1.24	30
12.5	20	10	.720	2.083	6.00	100.0	173.0	270.0	31
sec.-ft.	24	12	.788	3.000	4.17	36.7	62.9	97.6	32
or	32	16	.911	5.333	2.34	7.44	12.5	19.2	33
500	44	22	1.067	10.083	1.24	1.36	2.20	3.28	34
inches	54	27	1.183	15.188	0.82	0.47	0.75	1.09	35
17.5	24	12	.788	3.000	5.83	71.6	123.0	191.0	36
sec.-ft.	32	16	.911	5.333	3.28	14.6	24.6	37.8	37
or	44	22	1.067	10.083	1.74	2.61	4.27	6.47	38
700	54	27	1.183	15.188	1.15	0.88	1.40	2.09	39
inches	60	30	1.246	18.750	0.93	0.51	0.82	1.19	40

TABLE XXI.—KUTTER'S FORMULA (Con.)

FOR OPEN TRAPEZOIDAL CHANNELS AND  
CANALS IN LOOSE EARTH

The bank slopes are indicated in the figure.

The dimensions given are bottom width and  
depth of water.



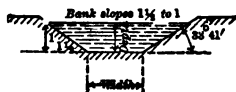
Quantity or Vol. of the Flow.	Width feet	Depth feet	$\sqrt{r}$ feet	Area sq.ft.	Mean Velocity Feet per Sec.	Grade, or Fall in Feet per Mile when			$\frac{C}{Z}$
						$n = .020$	$n = .025$	$n = .030$	
25.0	36	18	.968	7.875	3.17	11.5	19.2	29.4	41
sec.-ft.	48	24	1.117	14.000	1.79	2.42	3.94	5.93	42
or	60	30	1.249	21.875	1.14	0.75	1.19	1.78	43
1000	72	32	1.313	27.135	0.92	0.43	0.69	0.99	44
inches	84	35	1.373	32.915	0.76	0.27	0.42	0.61	45
37.5	42	21	1.045	10.719	3.50	11.1	18.4	27.9	46
sec.-ft.	48	24	1.117	14.000	2.68	5.36	8.84	13.3	47
or	60	30	1.249	21.875	1.71	1.63	2.61	3.84	48
1500	72	32	1.313	27.135	1.38	0.93	1.49	2.17	49
inches	96	37	1.430	39.215	0.96	0.37	0.57	0.83	50
50.0	4.	2.	1.117	14.00	3.57	9.50	15.7	23.6	51
sec.-ft.	5.	2.5	1.249	21.88	2.29	2.87	4.64	6.90	52
or	7.	2.9	1.373	32.92	1.52	0.99	1.58	2.30	53
2000	10.	3.3	1.501	49.34	1.01	0.36	0.54	0.79	54
inches	12.	3.5	1.566	60.38	0.83	0.21	0.33	0.48	55
75.0	4.5	2.25	1.185	17.72	4.23	11.3	18.5	27.6	56
sec.-ft.	6.	2.7	1.313	27.14	2.76	3.62	5.82	8.62	57
or	9.	3.2	1.466	44.16	1.70	1.03	1.63	2.36	58
3000	12.	3.5	1.566	60.38	1.24	0.46	0.73	1.05	59
inches	16.	3.8	1.666	82.46	0.91	0.21	0.33	0.48	60
125	6.	2.7	1.313	27.14	4.61	10.0	16.2	24.0	61
sec.-ft.	10.	3.3	1.501	49.34	2.53	2.11	3.34	4.86	62
or	14.	3.7	1.627	72.34	1.73	0.80	1.25	1.82	63
5000	18.	3.9	1.703	93.02	1.34	0.42	0.66	0.95	64
inches	24.	4.2	1.803	127.26	0.98	0.19	0.30	0.43	65
175	8.	3.1	1.430	39.22	4.46	7.41	11.9	17.4	66
sec.-ft.	12.	3.5	1.566	60.38	2.90	2.44	3.89	5.64	67
or	18.	3.9	1.703	93.02	1.88	0.83	1.29	1.87	68
7000	24.	4.2	1.803	127.26	1.38	0.38	0.59	0.85	69
inches	30.	4.5	1.891	165.38	1.06	0.20	0.30	0.43	70
250	12.	3.5	1.566	60.38	4.14	4.97	7.88	11.5	71
sec.-ft.	18.	3.9	1.703	93.02	2.69	1.68	2.64	3.82	72
or	24.	4.2	1.803	127.26	1.96	0.77	1.19	1.72	73
10,000	30.	4.5	1.891	165.38	1.51	0.40	0.62	0.89	74
inches	36.	4.8	1.972	207.36	1.21	0.22	0.35	0.50	75
375	18.	3.9	1.703	93.02	4.03	3.76	5.91	8.56	76
sec.-ft.	24.	4.2	1.803	127.26	2.95	1.73	2.70	3.89	77
or	30.	4.5	1.891	165.38	2.27	0.90	1.40	2.01	78
15,000	36.	4.8	1.972	207.36	1.81	0.51	0.78	1.12	79
inches	44.	5.2	2.072	269.36	1.39	0.25	0.39	0.56	80
500	22.	4.1	1.771	115.42	4.33	3.91	6.11	8.83	81
sec.-ft.	30.	4.5	1.891	165.38	3.02	1.59	2.48	3.56	82
or	36.	4.8	1.972	207.36	2.41	0.90	1.40	2.00	83
20,000	44.	5.2	2.072	269.36	1.86	0.46	0.72	1.03	84
inches	52.	5.6	2.164	338.24	1.48	0.25	0.39	0.56	85
750	30.	4.5	1.891	165.38	4.54	3.61	5.61	8.06	86
sec.-ft.	36.	4.8	1.972	207.36	3.62	2.04	3.18	4.55	87
or	44.	5.2	2.072	269.36	2.78	1.05	1.63	2.33	88
30,000	52.	5.6	2.164	338.24	2.22	0.59	0.91	1.29	89
inches	60.	6.	2.252	414.00	1.81	0.34	0.53	0.76	90

TABLE XXI.—KUTTER'S FORMULA (Con.)

FOR OPEN TRAPEZOIDAL CHANNELS AND  
CANALS IN LOOSE EARTH

The bank slopes are indicated in the figure.

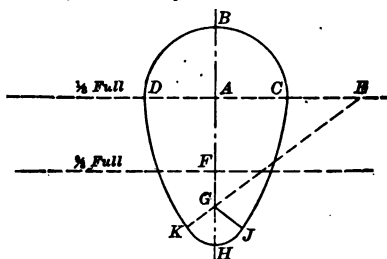
The dimensions given are bottom width and  
depth of water.



Quantity or Vol. of the Flow.	Width feet	Depth feet	$\sqrt{r}$ feet	Area sq. ft.	Mean Velocity Feet per Sec.	Grade, or Fall in Feet per Mile when			$\frac{C}{Z}$
						$n = .020$	$n = .025$	$n = .030$	
1250	44.	5.2	2.072	269.36	4.64	2.96	4.58	6.51	91
sec.-ft.	52.	5.6	2.164	338.24	3.70	1.67	2.58	3.65	92
or	60.	6.	2.252	414.00	3.02	0.99	1.53	2.16	93
50,000	70.	6.5	2.355	518.38	2.41	0.54	0.84	1.20	94
inches	80.	7.	2.454	633.50	1.97	0.32	0.49	0.70	95
1750	60.	6.	2.252	414.00	4.23	1.96	3.03	4.30	96
sec.-ft.	70.	6.5	2.355	518.38	3.38	1.10	1.69	2.39	97
or	80.	7.	2.454	633.50	2.76	0.65	1.00	1.42	98
70,000	90.	7.5	2.547	759.38	2.30	0.39	0.60	0.86	99
inches	100.	8.	2.637	896.00	1.95	0.25	0.38	0.55	100

### EGG-SHAPED CONDUITS

The egg-shaped conduit used by Mr. Flynn in compiling the table of factors that I have employed in computing the flowage tables that follow, has a *depth* or maximum vertical diameter



equal to 1.5 times its *width* or greatest transverse diameter. Its form is shown in the accompanying sketch and its geometrical proportions are given below.

$DC$ = Greatest transverse diameter	=	$X$
$BH$ = Greatest vertical diameter	=	$1.5 X$
$AC = AB = AD$ = radius of top section	=	$.5 X$
$GJ = GH = GK$ = radius of bottom section	=	$.25 X$
$ED = EK = BH$ = radius of sides	=	$1.5 X$
$AB = AF = FH$ = one-third of the depth ( $BH$ )	=	$.5 X$

	$\frac{1}{2}$ Full	$\frac{3}{4}$ Full	Running Full
Wet area	$= 0.284 \times X^2$	$0.7558 \times X^2$	$1.1485 \times X^2$
Wet perimeter	$= 1.3747 X$	$2.3941 X$	$3.9649 X$
Hydraulic mean depth $r$	$= 0.2066 X$	$0.3157 X$	$0.2897 X$

TABLE XXII.—FOR EGG-SHAPED CONDUITS

GIVING THE AREA, THE VALUE OF  $r$ , AND ITS SQUARE ROOT

1st, when one-third, 2d, when two-thirds, and 3d, when running full.

No.	When Running		One-third Full			Two-thirds Full			Running Full		
	Width feet	H'ght feet	Wet Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Wet Area sq.ft.	$r$ feet	$\sqrt{r}$ feet	Wet Area sq.ft.	$r$ feet	$\sqrt{r}$ feet
1	1.	1.5	.284	.207	.46	.76	.316	.56	1.15	.290	.54
2	1.167	1.75	.387	.241	.49	1.03	.368	.61	1.56	.338	.58
3	1.333	2.	.505	.276	.53	1.34	.421	.65	2.04	.386	.62
4	1.5	2.25	.639	.310	.56	1.70	.474	.69	2.58	.435	.66
5	1.667	2.5	.789	.344	.59	2.10	.526	.73	3.19	.483	.70
6	1.833	2.75	.955	.379	.62	2.54	.579	.76	3.86	.531	.73
7	2.	3.	1.136	.413	.64	3.02	.631	.80	4.59	.579	.76
8	2.167	3.25	1.333	.448	.67	3.55	.684	.83	5.39	.628	.79
9	2.333	3.5	1.546	.482	.69	4.11	.737	.86	6.25	.676	.82
10	2.5	3.75	1.775	.517	.72	4.72	.789	.89	7.18	.724	.85
11	2.667	4.	2.020	.551	.74	5.37	.842	.92	8.17	.773	.88
12	2.833	4.25	2.280	.585	.77	6.07	.895	.95	9.22	.821	.91
13	3.	4.5	2.556	.620	.79	6.80	.947	.97	10.34	.869	.93
14	3.167	4.75	2.848	.654	.81	7.58	1.007	1.00	11.52	.917	.96
15	3.333	5.	3.156	.689	.83	8.40	1.052	1.03	12.76	.966	.98
16	3.5	5.25	3.479	.723	.85	9.26	1.105	1.05	14.07	1.014	1.01
17	3.667	5.5	3.818	.758	.87	10.16	1.158	1.08	15.44	1.062	1.03
18	3.833	5.75	4.173	.792	.89	11.11	1.210	1.10	16.88	1.111	1.05
19	4.	6.	4.544	.826	.91	12.09	1.263	1.12	18.38	1.159	1.08
20	4.167	6.25	4.931	.861	.93	13.12	1.315	1.15	19.94	1.207	1.10
21	4.333	6.5	5.333	.895	.95	14.19	1.368	1.17	21.57	1.255	1.12
22	4.5	6.75	5.751	.930	.96	15.31	1.421	1.19	23.26	1.304	1.14
23	4.667	7.	6.185	.964	.98	16.46	1.473	1.21	25.01	1.352	1.16
24	4.833	7.25	6.634	.999	1.00	17.66	1.526	1.24	26.83	1.400	1.18
25	5.	7.5	7.100	1.033	1.02	18.90	1.579	1.26	28.71	1.449	1.20
26	5.167	7.75	7.581	1.067	1.03	20.18	1.631	1.28	30.66	1.497	1.22
27	5.333	8.	8.078	1.102	1.05	21.50	1.684	1.30	32.67	1.545	1.24
28	5.5	8.25	8.591	1.136	1.07	22.86	1.736	1.32	34.74	1.593	1.26
29	5.667	8.5	9.120	1.171	1.08	24.27	1.789	1.34	36.88	1.642	1.28
30	5.833	8.75	9.664	1.205	1.10	25.72	1.842	1.36	39.08	1.690	1.30
31	6.	9.	10.224	1.240	1.11	27.21	1.894	1.38	41.35	1.738	1.32
32	6.167	9.25	10.800	1.274	1.13	28.74	1.947	1.40	43.68	1.787	1.34
33	6.333	9.5	11.391	1.309	1.14	30.32	1.999	1.41	46.07	1.835	1.36
34	6.5	9.75	11.999	1.343	1.16	31.93	2.052	1.43	48.52	1.883	1.37
35	6.667	10.	12.622	1.377	1.17	33.59	2.105	1.45	51.05	1.931	1.39
36	6.833	10.25	13.261	1.412	1.19	35.29	2.157	1.47	53.63	1.980	1.41
37	7.	10.5	13.916	1.446	1.20	37.03	2.210	1.49	56.28	2.028	1.42
38	7.333	11.	15.273	1.515	1.23	40.65	2.315	1.52	61.76	2.125	1.46
39	7.667	11.5	16.693	1.584	1.26	44.43	2.420	1.56	67.51	2.221	1.49
40	8.	12.	18.176	1.653	1.29	48.37	2.526	1.59	73.50	2.318	1.52
41	8.333	12.5	19.722	1.722	1.31	52.49	2.631	1.62	79.76	2.414	1.55
42	8.667	13.	21.332	1.791	1.34	56.77	2.736	1.65	86.27	2.511	1.59
43	9.	13.5	23.004	1.859	1.36	61.22	2.841	1.69	93.03	2.607	1.62
44	9.333	14.	24.739	1.928	1.39	65.84	2.947	1.72	100.05	2.704	1.64
45	9.667	14.5	26.538	1.997	1.41	70.63	3.052	1.75	107.32	2.800	1.67
46	10.	15.	28.400	2.066	1.44	75.58	3.157	1.78	114.85	2.897	1.70
47	10.5	15.75	31.311	2.169	1.47	83.33	3.315	1.82	126.62	3.042	1.74
48	11.	16.5	34.364	2.273	1.51	91.45	3.473	1.86	138.97	3.187	1.79
49	12.	18.	40.896	2.479	1.58	108.84	3.788	1.95	165.38	3.476	1.87
50	13.333	20.	50.489	2.755	1.66	134.36	4.209	2.05	204.18	3.863	1.97

TABLE XXIII.—EGG-SHAPED CONDUITS,  
WHEN RUNNING ONE-THIRD FULL

## Kutter's Formula

When  $n$  equals .011.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Width feet	Height feet	Wet Area sq.ft.	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
					.01414 (1.06)	.01741 (1.60)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.05464 (15.8)
1	1.	1.5	.284	.455	.65 .18 .80	.79 .23 .98	1.02 0.29 1.27	1.45 0.41 1.79	2.05 0.58 2.54	2.50 0.71 3.10
2	1.33	2.	.505	.525	.41 .95 .75	.50 1.16 0.91	0.64 1.50 1.18	0.91 2.12 1.67	1.28 2.99 2.36	1.57 3.66 2.88
3	1.67	2.5	.789	.587	1.08 1.23 1.21	1.32 1.50 1.48	1.71 1.94 1.91	2.41 2.74 2.70	3.41 3.87 3.81	4.17 4.73 4.66
4	2.	3.	1.136	.643	1.86 1.32 2.67	2.28 1.62 3.26	2.95 2.09 4.22	4.17 2.95 5.97	5.90 4.18 8.44	7.20 5.10 10.31
5	2.33	3.5	1.546	.694	1.44 3.67 1.54	1.76 4.49 1.89	2.27 5.81 2.44	3.21 8.21 3.45	4.54 11.61 4.88	5.55 14.19 5.96
6	2.67	4.	2.020	.742	4.87 1.75 7.94	5.96 2.14 9.72	7.70 2.76 12.56	10.89 3.91 17.76	15.40 5.53 25.12	18.81 6.75 30.69
7	3.	4.5	2.556	.787	7.94 1.94 11.98	9.72 2.37 14.67	12.56 3.06 18.95	17.76 4.33 26.79	25.12 6.13 37.90	30.69 7.49 46.30
8	3.33	5.	3.156	.830	1.06 8.56 11.69	1.18 9.56 13.07	1.50 12.09 16.52	2.12 17.10 23.36	3.35 27.04 36.95	4.73 38.24 52.25
9	3.67	5.5	3.789	.867	1.14 10.11 13.23	1.28 10.56 14.37	1.62 13.07 17.73	2.29 19.04 25.45	3.61 30.94 4.88	5.11 48.91 6.79
10	4.	6.	4.544	.909	1.30 11.69 15.46	1.46 12.34 17.29	1.84 13.81 21.87	2.61 16.16 23.94	4.12 18.82 26.95	5.83 25.82 36.97
11	4.67	7.	6.185	.982	1.38 12.56 16.03	1.54 13.54 17.99	1.95 15.13 20.41	2.76 18.08 26.08	4.36 20.18 29.18	6.16 22.11 31.96
12	5.33	8.	8.078	1.050	1.45 30.91 1.52	1.62 34.56 1.70	2.05 43.71 2.15	2.90 61.82 3.04	4.58 97.74 4.80	6.48 138.23 6.79
13	5.67	8.5	8.822	1.083	1.59 37.58 45.01	1.77 42.01 50.35	2.24 53.14 63.67	3.17 78.16 90.06	5.01 118.82 142.37	7.09 168.06 201.26
14	6.	9.	10.224	1.113	1.68 47.80 1.78	1.88 64.64 1.99	2.38 81.75 2.51	3.36 115.60 3.55	5.32 182.82 5.62	7.52 258.82 7.95
15	6.67	10.	12.622	1.174	72.67 81.26 102.77	81.26 91.26 102.77	102.77 115.60 145.34	145.34 168.06 229.80	229.80 268.06 335.00	335.00 395.06 500.00
16	7.33	11.	15.273	1.231	1.45 30.91 1.52	1.62 34.56 1.70	2.05 43.71 2.15	2.90 61.82 3.04	4.58 97.74 4.80	6.48 138.23 6.79
17	7.67	11.5	16.022	1.264	1.59 37.58 45.01	1.77 42.01 50.35	2.24 53.14 63.67	3.17 78.16 90.06	5.01 118.82 142.37	7.09 168.06 201.26
18	8.	12.	18.176	1.286	1.68 47.80 1.78	1.88 64.64 1.99	2.38 81.75 2.51	3.36 115.60 3.55	5.32 182.82 5.62	7.52 258.82 7.95
19	8.67	13.	21.332	1.338	1.45 30.91 1.52	1.62 34.56 1.70	2.05 43.71 2.15	2.90 61.82 3.04	4.58 97.74 4.80	6.48 138.23 6.79
20	9.33	14.	24.739	1.389	1.59 37.58 45.01	1.77 42.01 50.35	2.24 53.14 63.67	3.17 78.16 90.06	5.01 118.82 142.37	7.09 168.06 201.26
21	10.	15.	28.400	1.437	1.68 47.80 1.78	1.88 64.64 1.99	2.38 81.75 2.51	3.36 115.60 3.55	5.32 182.82 5.62	7.52 258.82 7.95
22	10.67	15.5	30.022	1.467	1.78 50.35 53.14	1.99 70.35 73.14	2.51 81.75 84.53	3.55 115.60 118.39	5.62 182.82 185.61	7.95 258.82 261.60
23	11.	16.5	34.364	1.508	1.78 50.35 53.14	1.99 70.35 73.14	2.51 81.75 84.53	3.55 115.60 118.39	5.62 182.82 185.61	7.95 258.82 261.60
24	11.67	17.	38.896	1.555	1.78 50.35 53.14	1.99 70.35 73.14	2.51 81.75 84.53	3.55 115.60 118.39	5.62 182.82 185.61	7.95 258.82 261.60

TABLE XXIII.—EGG-SHAPED CONDUITS,  
WHEN RUNNING ONE-THIRD FULL (*Con.*)

## Kutter's Formula

When  $n$  equals .013.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Width feet	Height feet	Wet area sq.ft.	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
					.01741 (1.60)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.05464 (15.8)	.07071 (26.4)
1	1.	1.5	.284	.455	.64 .18	.82 .23	1.16 0.33	1.64 0.47	2.01 0.57	2.60 0.74
2	1.33	2.	.505	.525	.79 .40	1.03 0.52	1.45 0.73	2.05 1.04	2.51 1.27	3.24 1.64
3	1.67	2.5	.789	.587	.94 .74	1.21 0.96	1.72 1.36	2.43 1.92	2.97 2.34	3.84 3.03
4	2.	3.	1.136	.643	1.08 1.22	1.39 1.58	1.97 2.23	2.78 3.16	3.40 3.86	4.39 4.99
5	2.33	3.5	1.546	.694	1.21 1.87	1.56 2.41	2.21 3.41	3.12 4.82	3.81 5.89	4.93 7.62
6	2.67	4.	2.020	.742	1.33 2.68	1.71 3.46	2.42 4.89	3.43 6.92	4.19 8.45	5.42 10.94
7	3.	4.5	2.556	.787	1.45 3.69	1.87 4.77	2.64 6.78	3.74 9.55	4.56 11.66	5.91 18.09
8	3.33	5.	3.156	.830	1.56 4.91	2.01 6.34	2.84 8.97	4.02 12.68	4.91 15.49	6.35 20.05
9	4.	6.	4.544	.909	1.77 8.03	2.28 10.37	3.23 14.67	4.57 20.75	5.58 25.35	7.22 32.80
10	4.67	7.	6.185	.982	1.97 12.16	2.54 15.71	3.59 22.22	5.08 31.42	6.21 38.39	8.03 49.68
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	feet	feet	sq.ft.	feet	.00791 (.33)	.01000 (.528)	.01414 (1.06)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)
11	5.33	8.	8.078	1.050	.98 7.95	1.24 10.06	1.76 14.21	2.78 22.47	3.93 31.78	5.56 44.94
12	6.	9.	10.224	1.113	1.06 10.88	1.35 13.76	1.90 19.47	3.01 30.77	4.26 43.51	6.02 61.54
13	6.67	10.	12.622	1.174	1.14 14.41	1.45 18.24	2.04 25.80	3.23 40.78	4.57 57.68	6.46 81.56
14	7.33	11.	15.273	1.231	1.22 18.57	1.54 23.49	2.18 33.22	3.44 52.52	4.86 74.29	6.88 105.05
15	8.	12.	18.176	1.286	1.29 23.43	1.63 29.63	2.31 41.90	3.65 66.25	5.16 93.70	7.29 122.50
16	8.67	13.	21.332	1.338	1.36 28.95	1.72 36.63	2.43 51.79	3.84 81.89	5.43 115.83	7.68 163.81
17	9.33	14.	24.739	1.389	1.43 35.25	1.80 44.58	2.55 63.04	4.03 99.67	5.70 140.96	8.06 199.37
18	10.	15.	28.400	1.437	1.49 42.29	1.88 53.48	2.66 75.63	4.21 119.59	5.96 169.12	8.42 239.16
19	11.	16.5	34.364	1.508	1.58 54.40	2.00 68.80	2.83 97.28	4.48 153.85	6.33 217.56	8.95 307.66
20	12.	18.	40.896	1.575	1.67 68.46	2.12 86.58	2.99 122.44	4.73 193.60	6.70 273.80	9.47 387.16

TABLE XXIII.—EGG-SHAPED CONDUITS,  
WHEN RUNNING ONE-THIRD FULL (*Con.*)

**Kutter's Formula**

When  $n$  equals .015.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Width feet	Height feet	Wet area sq.ft.	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
					.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.05464 (15.8)	.07071 (26.4)	.10000 (52.8)
1	1.	1.5	.284	.455	.68 .19	.96 .27	1.36 0.39	1.66 0.47	2.15 0.61	3.04 0.86
2	1.33	2.	.505	.525	.85 .43	1.21 0.61	1.71 0.86	2.09 1.05	2.70 1.36	3.82 1.93
3	1.67	2.5	.789	.587	1.02 0.80	1.44 1.13	2.03 1.60	2.48 1.96	3.21 2.53	4.54 3.53
4	2.	3.	1.136	.643	1.17 1.32	1.65 1.87	2.33 2.65	2.85 3.23	3.68 4.18	5.21 5.92
5	2.33	3.5	1.546	.694	1.31 2.03	1.85 2.86	2.62 4.05	3.20 4.95	4.14 6.40	5.86 9.06
6	2.67	4.	2.020	.742	1.44 2.91	2.04 4.12	2.88 5.83	3.52 7.12	4.56 9.21	6.45 13.03
7	3.	4.5	2.556	.787	1.58 4.03	2.23 5.70	3.15 8.06	3.85 9.84	4.98 12.74	7.05 18.02
8	3.33	5.	3.156	.830	1.70 5.36	2.40 7.58	3.40 10.72	4.15 12.10	5.37 16.96	7.60 23.98
9	4.	6.	4.544	.909	1.94 8.80	2.74 12.45	3.87 17.60	4.73 21.50	6.12 27.83	8.66 39.36
10	4.67	7.	6.185	.982	2.16 13.35	3.05 18.89	4.32 26.71	5.28 32.63	6.83 42.23	9.66 59.73
					.01000 (.528)	.01414 (1.06)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)
11	5.33	8.	8.078	1.050	1.06 8.57	1.50 12.12	2.37 19.17	3.36 27.10	4.75 38.33	7.50 60.60
12	6.	9.	10.224	1.113	1.15 11.76	1.63 16.62	2.57 26.30	3.64 37.19	5.14 52.58	8.13 83.14
13	6.67	10.	12.622	1.174	1.24 15.61	1.75 22.08	2.77 34.91	3.91 49.38	5.53 69.83	7.75 110.41
14	7.33	11.	15.273	1.231	1.32 20.15	1.87 28.48	2.95 45.04	4.17 63.70	5.90 90.10	9.33 142.45
15	8.	12.	18.176	1.286	1.40 25.43	1.98 35.95	3.13 56.86	4.42 80.41	6.26 113.71	9.89 179.80
16	8.67	13.	21.332	1.338	1.48 31.47	2.09 44.50	3.30 70.35	4.66 99.49	6.60 140.71	10.43 222.49
17	9.33	14.	24.739	1.389	1.55 38.35	2.19 54.23	3.47 85.75	4.90 121.27	6.93 171.49	10.96 271.14
18	10.	15.	28.400	1.437	1.62 46.04	2.29 65.09	3.63 102.95	5.13 145.58	7.25 205.87	11.46 325.52
19	11.	16.5	34.364	1.508	1.73 59.31	2.44 83.88	3.86 132.65	5.46 187.56	7.72 265.26	12.21 419.41
20	12.	18.	40.896	1.575	1.83 74.88	2.59 105.88	4.09 167.43	5.79 236.79	8.19 334.86	12.95 629.48

TABLE XXIV.—EGG-SHAPED CONDUITS,  
WHEN RUNNING TWO-THIRDS FULL

## Kutter's Formula

When  $n$  equals .011.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Width feet.	Height feet.	Wet Area sq.ft.	$\sqrt{r}$ feet.	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
					.01414 (1.06)	.01741 (1.60)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.05464 (15.8)
1	1.	1.5	.756	.562	.89 1.67	1.09 0.82	1.40 1.06	1.98 1.50	2.80 2.12	3.43 2.59
2	1.33	2.	1.344	.649	1.09 1.47	1.34 1.80	1.73 2.32	2.44 3.29	3.46 4.65	4.22 5.67
3	1.67	2.5	2.099	.725	1.28 2.69	1.57 3.29	2.03 4.26	2.87 6.02	4.05 8.51	4.95 10.39
4	2.	3.	3.023	.795	1.46 4.40	1.78 5.38	2.30 6.96	3.25 9.84	4.60 13.91	5.62 17.00
5	2.33	3.5	4.115	.858	1.62 6.65	1.98 8.13	2.55 10.51	3.61 14.86	5.11 21.02	6.24 25.67
6	2.67	4.	5.375	.918	1.77 9.52	2.17 11.64	2.80 15.05	3.96 21.28	5.60 30.10	6.84 36.77
7	3.	4.5	6.802	.973	1.91 13.01	2.34 15.92	3.03 20.58	4.28 29.11	6.05 41.16	7.39 50.28
8	3.33	5.	8.398	1.025	2.05 17.24	2.51 21.10	3.25 27.27	4.59 33.56	6.49 54.53	7.93 66.62
9	4.	6.	12.093	1.124	2.32 28.00	2.83 34.26	3.66 44.26	5.18 62.61	7.32 85.53	8.94 108.16
10	4.67	7.	16.460	1.214	2.56 42.15	3.13 51.59	4.05 66.66	5.73 94.27	8.10 133.31	9.90 162.87
<hr/>										
	feet.	feet.	sq.ft.	feet.	.00707 (.264)	.00791 (.33)	.01000 (.528)	.01414 (1.06)	.02236 (2.64)	.03162 (5.28)
11	5.33	8.	21.50	1.298	1.39 29.97	1.56 33.52	1.97 42.39	2.79 59.96	4.41 94.81	6.2 134.1
12	6.	9.	27.21	1.376	1.50 40.84	1.68 45.66	2.12 57.77	3.00 81.68	4.75 129.17	6.7 182.7
13	6.67	10.	33.59	1.451	1.60 53.88	1.79 60.26	2.27 76.22	3.21 107.79	5.07 170.44	7.2 241.0
14	7.33	11.	40.65	1.522	1.70 69.22	1.90 77.39	2.41 97.87	3.41 138.40	5.39 218.87	7.6 309.8
15	8.	12.	48.37	1.589	1.80 86.92	2.01 97.18	2.54 122.91	3.59 173.80	5.68 274.84	8.0 388.7
16	8.67	13.	56.77	1.654	1.89 107.12	2.11 119.78	2.67 151.52	3.77 214.25	5.97 338.80	8.4 479.1
17	9.33	14.	65.84	1.717	1.98 130.10	2.21 145.44	2.79 183.95	3.95 260.13	6.25 411.36	8.8 581.7
18	10.	15.	75.58	1.777	2.06 155.70	2.30 174.06	2.91 230.17	4.12 311.39	6.51 492.33	9.2 696.2
19	11.	16.5	91.45	1.864	2.18 199.64	2.44 223.23	3.09 282.31	4.37 399.28	6.90 631.29	9.8 892.3
20	12.	18.	108.84	1.946	2.30 250.21	2.57 279.71	3.25 353.82	4.60 500.42	7.27 791.23	10.4 1118.9

TABLE XXIV.—EGG-SHAPED CONDUITS,  
WHEN RUNNING TWO-THIRDS FULL (Con.)

Kutter's Formula

When  $n$  equals .013.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Width feet	Height feet	Wet Area sq.ft.	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
					.01741 (1.60)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.05464 (15.8)	.07071 (26.4)
1	1.	1.5	.756	.562	.88 .67	1.14 0.86	1.61 1.22	2.27 1.72	2.78 2.10	3.59 2.72
2	1.33	2.	1.344	.649	1.09 1.47	1.41 1.89	1.99 2.68	2.82 3.79	3.44 4.63	4.46 5.99
3	1.67	2.5	2.099	.725	1.29 2.70	1.66 3.48	2.35 4.93	3.32 6.97	4.06 8.61	5.25 11.02
4	2.	3.	3.023	.795	1.46 4.43	1.89 5.72	2.68 8.09	3.78 11.44	4.62 13.97	5.98 18.08
5	2.33	3.5	4.115	.858	1.63 6.70	2.11 8.66	2.98 12.25	4.21 17.32	5.14 21.16	6.66 27.39
6	2.67	4.	5.375	.918	1.79 9.63	2.31 12.44	3.27 17.59	4.63 24.83	5.66 30.40	7.32 39.33
7	3.	4.5	6.802	.973	1.94 13.20	2.51 17.05	3.55 24.11	5.01 34.10	6.13 41.66	7.93 52.92
8	3.33	5.	8.398	1.025	2.09 17.53	2.70 22.65	3.81 32.03	5.39 48.29	6.69 56.33	8.53 71.62
9	4.	6.	12.093	1.124	2.36 28.54	3.05 36.88	4.31 52.16	6.10 73.77	7.45 90.12	9.65 116.64
10	4.67	7.	16.460	1.214	2.61 43.03	3.38 55.62	4.78 78.65	6.76 111.22	8.26 138.58	10.68 175.86
					.00791 (.33)	.01000 (.528)	.01414 (1.06)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)
11	5.33	8.	21.50	1.298	1.30 28.03	1.65 35.47	2.33 50.16	3.69 79.33	5.22 112.18	7.4 158.6
12	6.	9.	27.21	1.376	1.41 38.28	1.78 48.43	2.52 68.49	3.98 108.30	5.63 153.17	8.0 216.6
13	6.67	10.	33.59	1.451	1.51 50.66	1.91 64.06	2.70 90.60	4.26 143.23	6.03 202.59	8.5 236.5
14	7.33	11.	40.65	1.522	1.60 65.15	2.03 82.39	2.87 116.53	4.53 184.24	6.41 260.53	9.1 368.4
15	8.	12.	48.37	1.589	1.69 81.89	2.14 108.56	3.03 146.47	4.79 231.55	6.77 327.47	9.6 463.2
16	8.67	13.	56.77	1.654	1.78 101.05	2.25 127.79	3.18 180.70	5.03 235.72	7.12 404.08	10.1 571.5
17	9.33	14.	65.84	1.717	1.87 122.85	2.36 155.38	3.34 219.77	5.28 347.43	7.46 491.35	10.6 694.9
18	10.	15.	75.58	1.777	1.95 147.15	2.46 186.15	3.48 268.25	5.51 416.30	7.79 558.69	11.0 832.6
19	11.	16.5	91.45	1.864	2.07 189.03	2.61 239.06	3.70 538.10	5.85 854.54	8.27 1255.94	11.7 1669.1
20	12.	18.	108.84	1.946	2.18 227.26	2.76 300.06	3.90 424.35	6.17 670.97	8.72 948.82	12.3 1841.9

TABLE XXIV.—EGG-SHAPED CONDUITS,  
WHEN RUNNING TWO-THIRDS FULL (*Con.*)

## Kutter's Formula

When  $n$  equals .015.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Width feet	Height feet	Wet Area sq.ft.	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
					.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.05464 (15.8)	.07071 (26.4)	.10000 (52.8)
1	1.	1.5	.756	.562	.95 1.72	1.34 1.01	1.90 1.43	2.32 1.75	3.00 2.27	4.24 3.21
2	1.33	2.	1.344	.649	1.18 1.59	1.67 2.24	2.36 3.18	2.89 3.88	3.74 5.02	5.28 7.10
3	1.67	2.5	2.099	.725	1.40 2.93	1.98 4.15	2.79 5.86	3.41 7.16	4.42 9.27	6.25 13.11
4	2.	3.	3.023	.795	1.60 4.83	2.26 6.83	3.19 9.66	3.90 11.80	5.05 15.27	7.14 21.59
5	2.33	3.5	4.115	.858	1.78 7.33	2.52 10.37	3.56 14.67	4.35 17.92	5.64 23.19	7.97 32.79
6	2.67	4.	5.375	.918	1.96 10.56	2.78 14.93	3.93 21.11	4.80 25.79	6.21 33.38	8.78 47.20
7	3.	4.5	6.802	.973	2.13 14.50	3.02 20.51	4.26 29.00	5.21 35.43	6.74 45.85	9.53 64.84
8	3.33	5.	8.398	1.025	2.30 19.28	3.25 27.28	4.59 38.57	5.61 47.12	7.26 60.99	10.27 86.25
9	4.	6.	12.093	1.124	2.61 31.50	3.68 44.55	5.21 63.01	6.37 76.97	8.24 99.62	11.65 140.88
10	4.67	7.	16.460	1.214	2.89 47.64	4.09 67.35	5.79 95.25	7.07 116.37	9.15 150.61	12.94 212.99
					.01000 (.528)	.01414 (1.06)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.07071 (26.4)
11	5.33	8.	21.50	1.298	1.42 30.46	2.00 43.08	3.17 68.13	4.48 96.33	6.3 136.2	10.0 215.4
12	6.	9.	27.21	1.376	1.53 41.66	2.17 58.91	3.42 93.14	4.84 131.72	6.8 186.3	10.8 294.6
13	6.67	10.	33.59	1.451	1.64 55.16	2.32 78.00	3.67 123.35	5.19 174.40	7.3 248.7	11.6 390.0
14	7.33	11.	40.65	1.522	1.75 71.05	2.47 100.47	3.91 158.88	5.53 224.69	7.8 317.7	12.4 502.4
15	8.	12.	48.37	1.589	1.85 89.44	2.62 126.49	4.14 200.01	5.85 282.83	8.3 400.0	13.1 632.4
16	8.67	13.	56.77	1.654	1.95 110.47	2.75 156.23	4.35 247.00	6.15 349.36	8.7 494.1	13.8 781.1
17	9.33	14.	65.84	1.717	2.04 134.44	2.89 190.14	4.57 300.62	6.46 425.12	9.1 601.2	14.4 950.6
18	10.	15.	75.58	1.777	2.13 161.21	3.02 227.95	4.77 360.52	6.75 509.79	9.5 721.0	15.1 1139.9
19	11.	16.5	91.45	1.864	2.27 207.41	3.21 293.29	5.07 463.75	7.17 655.89	10.1 927.6	16.0 1466.6
20	12.	18.	108.84	1.946	2.39 260.55	3.39 368.52	5.35 582.59	7.57 823.99	10.7 1165.2	16.9 1842.4

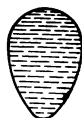
TABLE XXV.—EGG-SHAPED CONDUITS,  
WHEN RUNNING FULL

## Kutter's Formula

When  $n$  equals .011.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Width feet	Height feet	Area sq.ft.	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
					.01414 (1.06)	.01741 (1.60)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.05464 (15.8)
1	1.	1.5	1.148	.538	.83	1.02	1.32	1.86	2.63	3.21
2	1.33	2.	2.042	.622	.96	1.17	1.51	2.13	3.02	3.69
3	1.67	2.5	3.190	.695	1.03	1.26	1.63	2.30	3.25	3.97
4	2.	3.	4.594	.761	2.10	2.57	3.32	4.70	6.64	8.11
5	2.33	3.5	6.253	.822	1.21	1.47	1.91	2.69	3.81	4.66
6	2.67	4.	8.167	.879	3.84	4.70	6.08	8.59	12.15	14.85
7	3.	4.5	10.337	.932	1.37	1.68	2.17	3.06	4.33	5.29
8	3.33	5.	12.761	.983	6.29	7.70	9.95	14.06	19.89	24.30
9	4.	6.	18.376	1.076	1.52	1.86	2.41	3.41	4.82	5.88
10	4.67	7.	25.012	1.163	9.52	11.66	15.06	21.30	30.11	36.79
					1.67	2.04	2.64	3.73	5.28	6.45
					13.63	16.68	21.55	30.48	43.10	52.65
					1.81	2.21	2.86	4.04	5.71	6.98
					18.67	22.85	29.51	41.74	59.04	72.12
					1.94	2.37	3.07	4.34	6.13	7.49
					24.74	30.27	39.13	55.33	78.24	95.59
					2.19	2.68	3.46	4.89	6.92	8.45
					40.21	49.19	63.56	89.90	127.13	155.31
					2.42	2.96	3.82	5.41	7.65	9.34
					60.48	74.01	95.65	135.27	191.27	233.69
					.00707 (.264)	.00791 (.33)	.01000 (.526)	.01414 (1.06)	.02236 (2.64)	.03162 (5.28)
11	5.33	8.	32.67	1.243	1.32	1.47	1.87	2.64	4.2	5.9
12	6.	9.	41.35	1.318	43.09	48.15	60.93	86.15	126.2	192.7
13	6.67	10.	51.05	1.390	1.42	1.59	2.01	2.84	4.5	6.4
14	7.33	11.	61.76	1.458	58.75	65.70	83.11	117.55	185.9	262.8
15	8.	12.	73.50	1.522	1.52	1.70	2.15	3.04	4.8	6.8
16	8.67	13.	86.27	1.585	77.59	86.78	109.75	155.23	245.4	347.1
17	9.33	14.	100.05	1.644	1.61	1.80	2.28	3.23	5.1	7.2
18	10.	15.	114.85	1.702	99.62	111.36	140.88	199.25	315.1	445.5
19	11.	16.5	138.97	1.785	1.70	1.90	2.41	3.41	5.4	7.6
20	12.	18.	165.38	1.865	125.18	139.95	177.00	250.28	395.8	559.7
					1.79	2.00	2.53	3.58	5.7	8.0
					154.50	172.79	218.51	309.01	488.6	691.0
					1.87	2.09	2.65	2.75	5.9	8.4
					187.39	209.50	265.02	374.77	592.6	838.1
					1.96	2.19	2.77	3.91	6.2	8.7
					224.84	251.07	317.57	449.08	710.1	1004.3
					2.07	2.32	2.93	4.14	6.6	9.3
					287.81	321.85	407.04	575.61	910.2	1287.1
					2.18	2.44	3.09	4.37	6.9	9.8
					361.03	403.70	510.54	722.07	1141.6	1614.5

TABLE XXV.—EGG-SHAPED CONDUITS,  
WHEN RUNNING FULL (*Con.*)**Kutter's Formula**When  $n$  equals .013.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



No.	Width feet	Height feet	Area sq.ft.	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
					.01741 (1.60)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.05464 (15.8)	.07071 (26.4)
1	1.	1.5	1.148	.538	.82	1.06	1.51	2.13	2.60	3.36
					.95	1.22	1.73	2.44	2.99	3.86
2	1.33	2.	2.042	.622	1.02	1.32	1.87	2.65	3.23	4.19
					2.09	2.70	3.82	5.41	6.60	8.55
3	1.67	2.5	3.190	.695	1.21	1.56	2.21	3.12	3.81	4.93
					3.85	4.97	7.03	9.95	12.15	15.73
4	2.	3.	4.594	.761	1.37	1.78	2.51	3.55	4.34	5.62
					6.31	8.16	11.54	16.32	19.93	25.80
5	2.33	3.5	6.253	.822	1.53	1.98	2.80	3.96	4.84	6.27
					9.59	12.39	17.53	24.79	30.28	39.19
6	2.67	4.	8.167	.879	1.69	2.18	3.08	4.36	5.32	6.89
					13.76	17.79	25.15	35.58	43.47	56.25
7	3.	4.5	10.337	.932	1.83	2.36	3.34	4.72	5.77	7.47
					18.89	24.41	34.52	48.82	59.64	77.19
8	3.33	5.	12.761	.983	1.97	2.54	3.60	5.09	6.21	8.04
					25.10	32.44	45.89	64.89	79.27	102.60
9	4.	6.	18.376	1.076	2.23	2.88	4.07	5.76	7.04	9.11
					40.96	52.92	74.85	105.85	129.31	167.35
10	4.67	7.	25.012	1.163	2.47	3.19	4.51	6.38	7.80	10.09
					61.76	79.81	112.88	159.63	195.02	252.37
					.00701 (.33)	.01000 (.528)	.01414 (1.06)	.02236 (2.64)	.03162 (5.28)	.04472 (10.6)
11	5.33	8.	32.67	1.243	1.23	1.56	2.20	3.48	4.9	7.0
					40.25	50.90	71.97	113.82	161.0	227.6
12	6.	9.	41.35	1.318	1.33	1.68	2.38	3.76	5.3	7.5
					55.03	69.59	98.40	155.59	220.0	311.2
13	6.67	10.	51.05	1.390	1.43	1.80	2.55	4.03	5.7	8.1
					72.79	92.09	130.22	205.92	291.2	411.8
14	7.33	11.	61.76	1.458	1.52	1.92	2.71	4.29	6.1	8.6
					93.63	118.40	167.44	264.78	374.4	529.5
15	8.	12.	73.50	1.522	1.60	2.03	2.87	4.53	6.4	9.1
					117.83	148.99	210.74	333.19	471.2	666.3
16	8.67	13.	86.27	1.585	1.69	2.13	3.02	4.77	6.7	9.5
					145.53	184.09	260.35	411.66	582.1	823.2
17	9.33	14.	100.05	1.644	1.77	2.23	3.16	5.00	7.1	10.0
					176.68	223.50	316.05	499.73	706.8	999.6
18	10.	15.	114.85	1.702	1.85	2.33	3.30	5.22	7.4	10.4
					211.90	268.07	379.13	599.42	847.7	1198.8
19	11.	16.5	138.97	1.785	1.96	2.48	3.50	5.54	7.8	11.1
					272.10	334.23	486.81	769.75	1088.5	1539.4
20	12.	18.	165.38	1.865	2.07	2.61	3.70	5.85	8.3	11.7
					341.85	432.31	611.43	966.67	1367.1	1933.3

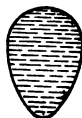
TABLE XXV.—EGG-SHAPED CONDUITS,  
WHEN RUNNING FULL (*Con.*)

## Kutter's Formula

When  $n$  equals .015.

Light type, the mean velocity in feet per second.

Heavy type, the discharge in cubic feet per second.



Width - feet	Height feet	Area sq.ft.	$\sqrt{r}$ feet	Square Root of Sine of Angle of Inclination. Figures in Parenthesis, Fall in Feet per Mile.					
				.02236 (2.64)	.03162 (5.28)	.04472 (10.6)	.05464 (15.8)	.07071 (26.4)	.10000 (52.8)
1.	1.5	1.148	.538	.89 1.02	1.25 1.44	1.77 2.03	2.17 2.49	2.80 3.22	3.96 4.55
1.33	2.	2.042	.622	1.11 2.26	1.57 3.20	2.22 4.53	2.71 5.53	3.51 7.16	4.96 10.12
1.67	2.5	3.190	.695	1.31 4.13	1.85 5.91	2.62 8.36	3.20 10.33	4.15 13.23	5.86 18.71
2.	3.	4.594	.761	1.50 6.88	2.12 9.73	2.99 13.75	3.66 16.80	4.73 21.74	6.69 30.75
2.33	3.5	6.253	.822	1.68 10.43	2.37 14.82	3.35 20.95	4.09 25.60	5.30 33.13	7.49 46.85
2.67	4.	8.167	.879	1.84 15.05	2.61 21.29	3.69 30.11	4.50 36.78	5.83 47.61	8.24 67.33
3.	4.5	10.337	.932	2.01 20.74	2.84 29.33	4.01 41.46	4.90 50.66	6.34 65.57	8.97 92.72
3.33	5.	12.761	.983	2.16 27.60	3.06 39.04	4.33 55.20	5.29 67.44	6.84 87.29	9.67 133.44
4.	6.	18.376	1.076	2.46 45.15	3.48 63.86	4.92 90.32	6.00 110.33	7.77 142.80	10.99 201.95
4.67	7.	25.012	1.163	2.73 68.28	3.86 96.57	5.46 136.57	6.67 166.86	8.63 216.95	12.21 305.40
5.33	8.	32.67	1.243	1.34 43.64	1.89 61.71	2.99 97.58	4.2 138.0	6.0 195.2	9.4 308.6
6.	9.	41.35	1.318	1.45 59.79	2.05 84.55	3.23 132.67	4.6 189.1	6.5 267.4	10.2 422.8
6.67	10.	51.05	1.390	1.55 79.22	2.20 112.04	3.47 177.13	4.9 250.5	6.9 354.3	11.0 560.2
7.33	11.	61.76	1.458	1.65 101.91	2.33 144.09	3.69 227.91	5.2 322.3	7.4 455.7	11.7 720.6
8.	12.	73.50	1.522	1.75 123.49	2.47 181.70	3.91 287.33	5.5 406.3	7.8 574.6	12.4 908.5
8.67	13.	86.27	1.585	1.84 155.99	2.61 224.81	4.12 355.50	5.8 502.8	8.2 711.0	13.0 1124.2
9.33	14.	100.05	1.644	1.93 193.19	2.73 273.23	4.32 432.00	6.1 610.9	8.6 864.0	13.7 1366.0
10.	15.	114.85	1.702	2.02 231.89	2.86 327.91	4.52 518.56	6.4 733.3	9.0 1037.0	14.3 1639.6
11.	16.5	138.97	1.785	2.15 298.23	3.04 421.77	4.80 666.91	8.8 943.0	9.6 1333.7	15.2 2108.7
12.	18.	165.38	1.865	2.27 375.09	3.21 530.39	5.07 838.66	7.2 1186.1	10.1 1677.5	16.0 2652.3

TABLE XXVI.—GRADUATED VALUES FOR HYDRAULIC RADIUS ( $r$ ) AND ITS SQUARE ROOT,  $\sqrt{r}$ 

$r$ feet	$\sqrt{r}$ feet	$r$ feet	$\sqrt{r}$ feet	$r$ feet	$\sqrt{r}$ feet	$r$ feet	$\sqrt{r}$ feet
.005	.07071	.115	.3391	.380	.6164	.645	.8031
.006	.07746	.120	.3464	.385	.6205	.650	.8062
.007	.08367	.125	.3536	.390	.6245	.655	.8093
.008	.08944	.130	.3606	.395	.6285	.660	.8124
.009	.09487	.135	.3674	.400	.6325	.665	.8155
.010	.10000	.140	.3742	.405	.6364	.670	.8185
.012	.10955	.145	.3808	.410	.6403	.675	.8216
.014	.11832	.150	.3873	.415	.6442	.680	.8246
.016	.12649	.155	.3937	.420	.6481	.685	.8276
.018	.13416	.160	.4000	.425	.6519	.690	.8307
.020	.14142	.165	.4062	.430	.6557	.695	.8337
.022	.14832	.170	.4123	.435	.6595	.700	.8367
.024	.15492	.175	.4183	.440	.6633	.705	.8396
.026	.16125	.180	.4243	.445	.6671	.710	.8426
.028	.16733	.185	.4301	.450	.6708	.715	.8456
.030	.17321	.190	.4359	.455	.6745	.720	.8485
.032	.17889	.195	.4416	.460	.6782	.725	.8515
.034	.18439	.200	.4472	.465	.6819	.730	.8544
.036	.18974	.205	.4528	.470	.6856	.735	.8573
.038	.19494	.210	.4583	.475	.6892	.740	.8602
.040	.20000	.215	.4637	.480	.6928	.745	.8631
.042	.20494	.220	.4690	.485	.6964	.750	.8660
.044	.20976	.225	.4743	.490	.7000	.755	.8689
.046	.21448	.230	.4796	.495	.7036	.760	.8718
.048	.21909	.235	.4848	.500	.7071	.765	.8746
.050	.22361	.240	.4899	.505	.7106	.770	.8775
.052	.22804	.245	.4950	.510	.7141	.775	.8803
.054	.23238	.250	.5000	.515	.7176	.780	.8832
.056	.23664	.255	.5050	.520	.7211	.785	.8860
.058	.24083	.260	.5099	.525	.7246	.790	.8888
.060	.24495	.265	.5148	.530	.7280	.795	.8916
.062	.24900	.270	.5196	.535	.7314	.800	.8944
.064	.25298	.275	.5244	.540	.7348	.805	.8972
.066	.25691	.280	.5292	.545	.7382	.810	.9000
.068	.26077	.285	.5339	.550	.7416	.815	.9028
.070	.26458	.290	.5385	.555	.7450	.820	.9055
.072	.26833	.295	.5431	.560	.7483	.825	.9083
.074	.27203	.300	.5477	.565	.7517	.830	.9110
.076	.27568	.305	.5523	.570	.7550	.835	.9138
.078	.27929	.310	.5568	.575	.7583	.840	.9165
.080	.28284	.315	.5612	.580	.7616	.845	.9192
.082	.28636	.320	.5657	.585	.7649	.850	.9220
.084	.28983	.325	.5701	.590	.7681	.855	.9247
.086	.29326	.330	.5745	.595	.7714	.860	.9274
.088	.29665	.335	.5788	.600	.7746	.865	.9301
.090	.30000	.340	.5831	.605	.7778	.870	.9327
.092	.30332	.345	.5874	.610	.7810	.875	.9354
.094	.30659	.350	.5916	.615	.7842	.880	.9381
.096	.30984	.355	.5958	.620	.7874	.885	.9407
.098	.31305	.360	.6000	.625	.7906	.890	.9434
.100	.31623	.365	.6042	.630	.7937	.895	.9460
.105	.32404	.370	.6083	.635	.7969	.900	.9487
.110	.33166	.375	.6124	.640	.8000	.905	.9513

TABLE XXVI.—GRADUATED VALUES FOR HYDRAULIC RADIUS ( $r$ ) AND ITS SQUARE ROOT,  $\sqrt{r}$  (Con.)

$r$ feet	$\sqrt{r}$ feet	$r$ feet	$\sqrt{r}$ feet	$r$ feet	$\sqrt{r}$ feet	$r$ feet	$\sqrt{r}$ feet
.910	.9539	1.35	1.1619	1.88	1.3711	2.41	1.5524
.915	.9566	1.36	1.1662	1.89	1.3748	2.42	1.5556
.920	.9592	1.37	1.1705	1.90	1.3784	2.43	1.5589
.925	.9618	1.38	1.1747	1.91	1.3820	2.44	1.5621
.930	.9644	1.39	1.1790	1.92	1.3856	2.45	1.5653
.935	.9670	1.40	1.1832	1.93	1.3892	2.46	1.5684
.940	.9695	1.41	1.1874	1.94	1.3928	2.47	1.5716
.945	.9721	1.42	1.1916	1.95	1.3964	2.48	1.5748
.950	.9747	1.43	1.1958	1.96	1.4000	2.49	1.5780
.955	.9772	1.44	1.2000	1.97	1.4036	2.50	1.5811
.960	.9798	1.45	1.2042	1.98	1.4071	2.52	1.5875
.965	.9823	1.46	1.2083	1.99	1.4107	2.54	1.5937
.970	.9849	1.47	1.2124	2.00	1.4142	2.56	1.6000
.975	.9874	1.48	1.2166	2.01	1.4177	2.58	1.6062
.980	.9899	1.49	1.2207	2.02	1.4213	2.60	1.6125
.985	.9925	1.50	1.2247	2.03	1.4248	2.62	1.6186
.990	.9950	1.51	1.2288	2.04	1.4283	2.64	1.6248
.995	.9975	1.52	1.2329	2.05	1.4318	2.66	1.6310
1.00	1.0000	1.53	1.2370	2.06	1.4353	2.68	1.6371
1.01	1.0050	1.54	1.2410	2.07	1.4388	2.70	1.6432
1.02	1.0100	1.55	1.2450	2.08	1.4422	2.72	1.6492
1.03	1.0149	1.56	1.2490	2.09	1.4457	2.74	1.6553
1.04	1.0198	1.57	1.2530	2.10	1.4491	2.76	1.6613
1.05	1.0247	1.58	1.2570	2.11	1.4526	2.78	1.6673
1.06	1.0296	1.59	1.2610	2.12	1.4560	2.80	1.6733
1.07	1.0344	1.60	1.2649	2.13	1.4595	2.82	1.6793
1.08	1.0392	1.61	1.2689	2.14	1.4629	2.84	1.6852
1.09	1.0440	1.62	1.2728	2.15	1.4663	2.86	1.6912
1.10	1.0488	1.63	1.2767	2.16	1.4697	2.88	1.6971
1.11	1.0536	1.64	1.2806	2.17	1.4731	2.90	1.7029
1.12	1.0583	1.65	1.2845	2.18	1.4765	2.92	1.7088
1.13	1.0630	1.66	1.2884	2.19	1.4799	2.94	1.7146
1.14	1.0677	1.67	1.2923	2.20	1.4832	2.96	1.7205
1.15	1.0724	1.68	1.2962	2.21	1.4866	2.98	1.7263
1.16	1.0770	1.69	1.3000	2.22	1.4900	3.00	1.7321
1.17	1.0817	1.70	1.3038	2.23	1.4933	3.02	1.7378
1.18	1.0863	1.71	1.3077	2.24	1.4967	3.04	1.7436
1.19	1.0909	1.72	1.3115	2.25	1.5000	3.06	1.7493
1.20	1.0955	1.73	1.3153	2.26	1.5033	3.08	1.7550
1.21	1.1000	1.74	1.3191	2.27	1.5067	3.10	1.7607
1.22	1.1045	1.75	1.3229	2.28	1.5100	3.12	1.7664
1.23	1.1091	1.76	1.3267	2.29	1.5133	3.14	1.7720
1.24	1.1136	1.77	1.3304	2.30	1.5166	3.16	1.7776
1.25	1.1180	1.78	1.3342	2.31	1.5199	3.18	1.7833
1.26	1.1225	1.79	1.3379	2.32	1.5232	3.20	1.7889
1.27	1.1269	1.80	1.3416	2.33	1.5264	3.22	1.7944
1.28	1.1314	1.81	1.3454	2.34	1.5297	3.24	1.8000
1.29	1.1358	1.82	1.3491	2.35	1.5330	3.26	1.8056
1.30	1.1402	1.83	1.3528	2.36	1.5362	3.28	1.8111
1.31	1.1446	1.84	1.3565	2.37	1.5395	3.30	1.8166
1.32	1.1489	1.85	1.3602	2.38	1.5427	3.32	1.8221
1.33	1.1533	1.86	1.3638	2.39	1.5460	3.34	1.8276
1.34	1.1576	1.87	1.3675	2.40	1.5492	3.36	1.8330

TABLE XXVI.—GRADUATED VALUES FOR HYDRAULIC RADIUS ( $r$ ) AND ITS SQUARE ROOT,  $\sqrt{r}$  (Con.)

$r$ feet	$\sqrt{r}$ feet	$r$ feet	$\sqrt{r}$ feet	$r$ feet	$\sqrt{r}$ feet	$r$ feet	$\sqrt{r}$ feet
3.38	1.8385	4.28	2.0688	5.45	2.3345	7.75	2.7839
3.40	1.8439	4.30	2.0736	5.50	2.3452	7.80	2.7929
3.42	1.8493	4.32	2.0785	5.55	2.3558	7.85	2.8018
3.44	1.8547	4.34	2.0833	5.60	2.3664	7.90	2.8107
3.46	1.8601	4.36	2.0881	5.65	2.3770	7.95	2.8196
3.48	1.8655	4.38	2.0928	5.70	2.3875	8.00	2.8284
3.50	1.8708	4.40	2.0976	5.75	2.3979	8.05	2.8373
3.52	1.8762	4.42	2.1024	5.80	2.4083	8.10	2.8461
3.54	1.8815	4.44	2.1071	5.85	2.4187	8.15	2.8548
3.56	1.8868	4.46	2.1119	5.90	2.4290	8.20	2.8636
3.58	1.8921	4.48	2.1166	5.95	2.4393	8.25	2.8723
3.60	1.8974	4.50	2.1213	6.00	2.4495	8.30	2.8810
3.62	1.9026	4.52	2.1260	6.05	2.4597	8.35	2.8896
3.64	1.9079	4.54	2.1307	6.10	2.4698	8.40	2.8983
3.66	1.9131	4.56	2.1354	6.15	2.4799	8.45	2.9069
3.68	1.9183	4.58	2.1401	6.20	2.4900	8.50	2.9155
3.70	1.9235	4.60	2.1448	6.25	2.5000	8.55	2.9240
3.72	1.9287	4.62	2.1494	6.30	2.5100	8.60	2.9326
3.74	1.9339	4.64	2.1541	6.35	2.5199	8.65	2.9411
3.76	1.9391	4.66	2.1587	6.40	2.5298	8.70	2.9496
3.78	1.9442	4.68	2.1633	6.45	2.5397	8.75	2.9580
3.80	1.9494	4.70	2.1680	6.50	2.5495	8.80	2.9665
3.82	1.9545	4.72	2.1726	6.55	2.5593	8.85	2.9749
3.84	1.9596	4.74	2.1772	6.60	2.5691	8.90	2.9833
3.86	1.9647	4.76	2.1817	6.65	2.5788	8.95	2.9917
3.88	1.9698	4.78	2.1863	6.70	2.5884	9.00	3.0000
3.90	1.9748	4.80	2.1909	6.75	2.5981	9.05	3.0083
3.92	1.9799	4.82	2.1955	6.80	2.6077	9.10	3.0166
3.94	1.9849	4.84	2.2000	6.85	2.6173	9.15	3.0249
3.96	1.9900	4.86	2.2045	6.90	2.6268	9.20	3.0332
3.98	1.9950	4.88	2.2091	6.95	2.6363	9.25	3.0414
4.00	2.0000	4.90	2.2136	7.00	2.6458	9.30	3.0496
4.02	2.0050	4.92	2.2181	7.05	2.6552	9.35	3.0578
4.04	2.0100	4.94	2.2226	7.10	2.6646	9.40	3.0659
4.06	2.0149	4.96	2.2271	7.15	2.6740	9.45	3.0741
4.08	2.0199	4.98	2.2316	7.20	2.6833	9.50	3.0822
4.10	2.0249	5.00	2.2361	7.25	2.6926	9.55	3.0903
4.12	2.0298	5.05	2.2472	7.30	2.7019	9.60	3.0984
4.14	2.0347	5.10	2.2583	7.35	2.7111	9.65	3.1064
4.16	2.0396	5.15	2.2694	7.40	2.7203	9.70	3.1145
4.18	2.0445	5.20	2.2804	7.45	2.7295	9.75	3.1225
4.20	2.0494	5.25	2.2913	7.50	2.7386	9.80	3.1305
4.22	2.0543	5.30	2.3022	7.55	2.7477	9.85	3.1385
4.24	2.0591	5.35	2.3130	7.60	2.7568	9.90	3.1464
4.26	2.0640	5.40	2.3238	7.65	2.7659	9.95	3.1544
				7.70	2.7749	10.00	3.1623

TABLE XXVII.—ELEMENTS OF SLOPE

Giving the ratio of the head to the distance, the sine of the angle of inclination, or the value of  $s$ , and its square root, the fall in feet per mile, and the fall in 100 feet or the per cent of grade.

Slope 1 in	Sine of slope-angle = $s$	$\sqrt{s}$	Fall in Feet per Mile.	Fall in 100 ft. or % of Grade.
4	.25	.5	1320.	25.
5	.2	.447214	1056.	20.
6	.1666667	.408248	880.	16.67
7	.14285714	.377978	754.3	14.29
8	.125	.353553	660.	12.5
9	.11111111	.333333	586.7	11.11
10	.1	.316228	528.	10.
11	.09090909	.301511	480.	9.09
12	.08333333	.288675	440.	8.33
13	.07692308	.277350	406.2	7.69
14	.07142857	.267261	377.1	7.14
15	.06666667	.258199	352.	6.67
16	.0625	.25	330.	6.25
17	.05882353	.242536	310.6	5.88
18	.05555555	.235702	293.2	5.56
19	.05263158	.229416	277.9	5.26
20	.05	.223607	264.	5.
21	.04761905	.218218	251.4	4.76
22	.04545454	.2132	240.	4.55
23	.04347826	.208514	229.6	4.35
24	.04166667	.204124	220.	4.17
25	.04	.2	211.2	4.
26	.03846154	.196116	203.1	3.85
27	.03703704	.192450	195.6	3.70
28	.03571429	.188982	188.6	3.57
29	.03445276	.185695	182.1	3.45
30	.03333333	.182574	176.	3.33
32	.03125	.176777	165.	3.13
34	.02941177	.171499	155.3	2.94
36	.02777778	.166667	146.7	2.78
38	.02631579	.162221	138.9	2.63
40	.025	.158114	132.	2.5
42	.02380952	.154303	125.7	2.38
44	.02272727	.150756	120.	2.27
46	.02173913	.147444	114.8	2.17
48	.02083333	.144337	110.	2.08
50	.02	.141421	105.6	2.
52	.01923077	.138676	101.5	1.92
54	.01851852	.136085	97.78	1.85
56	.01785014	.133630	94.29	1.79
58	.01724138	.131305	91.03	1.72
60	.01666667	.129100	88.	1.67
62	.01612903	.127000	85.16	1.61
64	.015625	.125	82.50	1.56
66	.01515152	.123091	80.	1.52
68	.01470588	.121286	77.65	1.47
70	.01428571	.119524	75.43	1.43
72	.01388889	.117851	73.33	1.39
74	.01351351	.116248	71.35	1.35
76	.01315790	.114708	69.47	1.32

TABLE XXVII.—ELEMENTS OF SLOPE (Con.)

Giving the ratio of the head to the distance, the sine of the angle of inclination, or the value of  $s$ , and its square root, the fall in feet per mile, and the fall in 100 feet or the per cent of grade.

Slope 1 in	Sine of Slope-angle = $s$ .	$\sqrt{s}$ .	Fall in Feet per Mile.	Fall in 100 ft. or % of Grade.
78	.01282051	.113228	67.69	1.282
80	.0125	.111803	66.	1.250
82	.01219512	.110431	64.39	1.220
84	.01190476	.109109	62.80	1.190
86	.01162791	.107833	61.40	1.163
88	.01136364	.106600	60.	1.140
90	.01111111	.105409	58.66	1.111
92	.01086957	.104257	57.39	1.090
94	.01063830	.103142	56.17	1.064
96	.01041667	.102062	55.	1.042
98	.01020408	.101015	53.88	1.020
100	.01	.1	52.8	1.
104	.00961539	.098058	50.77	.962
108	.00925926	.096225	48.89	.936
112	.00892857	.094491	47.14	.893
116	.00862069	.092848	45.52	.862
120	.00833333	.091287	44.	.833
124	.00806452	.089803	42.58	.810
128	.00781250	.088388	41.25	.781
132	.00757576	.087039	40.	.760
136	.00735294	.085749	38.82	.740
140	.00714286	.084516	37.71	.714
144	.00694444	.083333	36.67	.694
148	.00675676	.082199	35.68	.680
152	.00657895	.081111	34.74	.660
156	.00641026	.080065	33.85	.641
160	.00625	.079057	33.	.630
164	.00609756	.078087	32.20	.610
168	.00595238	.077152	31.43	.595
172	.00581395	.076249	30.70	.581
176	.00568182	.075378	30.	.568
180	.00555556	.074536	29.33	.556
184	.00543478	.073721	28.70	.543
188	.00531915	.072932	28.09	.532
192	.00520833	.072169	27.50	.520
196	.00510204	.071429	26.94	.510
200	.005	.070710	26.40	.5
205	.00487805	.069843	25.76	.488
210	.00476191	.069007	25.14	.476
215	.00465116	.068199	24.56	.465
220	.00454545	.067419	24.	.455
225	.00444444	.066667	23.47	.444
230	.00434783	.065938	22.96	.435
235	.00425532	.065233	22.48	.426
240	.00416667	.064549	22.	.417
245	.00408162	.063885	21.55	.408
250	.004	.063246	21.12	.4
255	.00392157	.062620	20.71	.392
260	.00384615	.062018	20.31	.385
265	.00377359	.061430	19.92	.377

TABLE XXVII.—ELEMENTS OF SLOPE *Con.*)

Giving the ratio of the head to the distance, the sine of the angle of inclination, or the value of  $s$ , and its square root, the fall in feet per mile, and the fall in 100 feet or the per cent of grade.

Slope 1 in	Sine of Slope-angle = $s$ .	$\sqrt{s}$ .	Fall in Feet per Mile.	Fall in 100 ft. or % of Grade.
270	.00370370	.060858	19.56	.370
275	.00363363	.060302	19.20	.363
280	.00357143	.059761	18.86	.357
285	.00350877	.059235	18.53	.351
290	.00344828	.058722	18.20	.345
295	.00338983	.058222	17.90	.339
300	.00333333	.057735	17.60	.333
310	.00322581	.056796	17.03	.323
320	.003125	.055902	16.50	.313
330	.00303030	.055048	16.	.303
340	.00294118	.054232	15.53	.294
350	.00285714	.053452	15.09	.286
360	.00277778	.052705	14.67	.278
370	.00270270	.051988	14.27	.270
380	.00263158	.051299	13.90	.263
390	.00256410	.050637	13.54	.256
400	.0025	.05	13.20	.25
410	.00243902	.049387	12.88	.244
420	.00238095	.048795	12.57	.238
430	.00232558	.048224	12.28	.233
440	.00227273	.047673	12.	.227
450	.00222222	.047140	11.73	.222
460	.00217391	.046625	11.48	.217
470	.00212766	.046126	11.24	.213
480	.00208333	.045644	11.	.208
490	.00204082	.045175	10.78	.204
500	.002	.044721	10.56	.200
510	.00196078	.044281	10.35	.196
520	.00192308	.043853	10.15	.192
530	.00188679	.043437	9.96	.189
540	.00185185	.043033	9.78	.185
550	.00181818	.042640	9.60	.182
560	.00178571	.042258	9.43	.179
570	.00175439	.041885	9.26	.175
580	.00172414	.041523	9.10	.172
590	.00169492	.041169	8.95	.169
600	.00166667	.040825	8.80	.167
620	.00161290	.040161	8.52	.161
640	.00156250	.039528	8.25	.156
660	.00151515	.038925	8.	.152
680	.00147059	.038348	7.77	.147
700	.00142857	.037796	7.54	.143
720	.00138889	.037268	7.33	.139
740	.00135135	.036761	7.14	.135
760	.00131579	.036274	6.95	.132
780	.00128205	.035806	6.77	.128
800	.00125	.035355	6.60	.125
820	.00121951	.034922	6.44	.122
840	.00119048	.034503	6.29	.119
860	.00116279	.034099	6.14	.116

TABLE XXVII.—ELEMENTS OF SLOPE (*Con.*)

Giving the ratio of the head to the distance, the sine of the angle of inclination, or the value of  $s$ , and its square root, the fall in feet per mile, and the fall in 100 feet or the per cent of grade.

Slope 1 in	Sine of Slope-angle = $s$ .	$\sqrt{s}$ .	Fall in Feet per Mile.	Fall in 100 ft. or % of Grade.
880	.00113636	.033710	6.	.1140
900	.00111111	.033333	5.87	.1111
920	.00108696	.032969	5.74	.1090
940	.00106383	.032616	5.62	.1064
960	.00104167	.032275	5.50	.1042
980	.00102041	.031944	5.39	.1020
1000	.001	.031623	5.28	.1000
1040	.00096154	.031009	5.08	.0962
1080	.00092593	.030429	4.89	.0930
1120	.00089286	.029881	4.71	.0893
1160	.00086207	.029361	4.55	.0862
1200	.00083333	.028868	4.40	.0833
1240	.00080645	.028398	4.26	.0806
1280	.00078125	.027951	4.13	.0781
1320	.00075758	.027524	4.	.0758
1360	.00073529	.027116	3.88	.0735
1400	.00071429	.026726	3.77	.0714
1440	.00069444	.026352	3.67	.0694
1480	.00067568	.025994	3.57	.0676
1520	.00065790	.025649	3.47	.0658
1560	.00064103	.025318	3.39	.0641
1600	.00062500	.025	3.30	.0625
1640	.00060976	.024693	3.22	.0610
1680	.00059524	.024398	3.14	.0595
1720	.00058140	.024112	3.07	.0581
1760	.00056818	.023837	3.	.0568
1800	.00055556	.023570	2.93	.0556
1840	.00054348	.023313	2.87	.0543
1880	.00053192	.023063	2.81	.0532
1920	.00052083	.022822	2.75	.0521
1960	.00051020	.022588	2.69	.0510
2000	.0005	.022361	2.64	.05
2050	.00048781	.022086	2.58	.0488
2100	.00047619	.021822	2.51	.0476
2150	.00046512	.021567	2.46	.0465
2200	.00045455	.021320	2.40	.0455
2250	.00044444	.021082	2.35	.0444
2300	.00043478	.020853	2.30	.0435
2350	.00042553	.020628	2.25	.0426
2400	.00041667	.020412	2.20	.0417
2450	.00040816	.020203	2.16	.0409
2500	.0004	.02	2.11	.04
2550	.00039216	.019803	2.07	.0392
2600	.00038462	.019612	2.03	.0385
2650	.00037736	.019426	1.99	.0377
2700	.00037037	.019245	1.96	.0370
2750	.00036364	.019069	1.92	.0364
2800	.00035714	.018898	1.89	.0357
2850	.00035088	.018731	1.85	.0351
2900	.00034483	.018569	1.82	.0345

TABLE XXVII.—ELEMENTS OF SLOPE (Con.)

Giving the ratio of the head to the distance, the sine of the angle of inclination, or the value of  $s$ , and its square root, the fall in feet per mile, and the fall in 100 feet or the per cent of grade.

Slope 1 in	Sine of Slope- angle = $s$ .	$\sqrt{s}$ .	Fall in Feet per Mile.	Fall in 100 ft. or % of Grade.
2,950	.00033898	.018414	1.79	.0339
3,000	.00033333	.018257	1.76	.0333
3,100	.00032258	.017960	1.70	.0323
3,200	.00031250	.017677	1.65	.0313
3,300	.00030303	.017408	1.6	.0303
3,400	.00029412	.017150	1.553	.0294
3,500	.00028571	.016903	1.509	.0286
3,600	.00027778	.016667	1.467	.0278
3,700	.00027027	.016440	1.427	.0270
3,800	.00026316	.016222	1.390	.0263
3,900	.00025641	.016013	1.354	.0256
4,000	.00025	.015811	1.320	.0250
4,100	.00024390	.015617	1.288	.0244
4,200	.00023810	.015430	1.257	.0238
4,300	.00023256	.015250	1.228	.0233
4,400	.00022727	.015076	1.2	.0227
4,500	.00022222	.014907	1.173	.0222
4,600	.00021739	.014744	1.148	.0217
4,700	.00021277	.014586	1.124	.0213
4,800	.00020833	.014434	1.1	.0208
4,900	.00020408	.014285	1.078	.0204
5,000	.0002	.014142	1.056	.0200
5,200	.00019231	.013888	1.015	.0192
5,400	.00018519	.013608	.978	.0185
5,600	.00017857	.013363	.943	.0179
5,800	.00017241	.013131	.910	.0172
6,000	.00016667	.012910	.880	.0167
6,200	.00016129	.012700	.852	.0161
6,400	.00015625	.0125	.825	.0156
6,600	.00015152	.012309	.800	.0151
6,800	.00014706	.012127	.777	.0147
7,000	.00014286	.011952	.754	.0143
7,200	.00013889	.011785	.733	.0139
7,400	.00013514	.011625	.714	.0135
7,600	.00013158	.011471	.695	.0132
7,800	.00012821	.011323	.677	.0128
8,000	.000125	.011180	.660	.0125
8,200	.00012195	.011043	.644	.0122
8,400	.00011905	.010911	.629	.0119
8,600	.00011628	.010783	.614	.0116
8,800	.00011364	.010660	.600	.0114
9,000	.00011111	.010541	.587	.0111
9,200	.00010870	.010427	.574	.0109
9,400	.00010638	.010314	.562	.0106
9,600	.00010417	.010206	.550	.0104
9,800	.00010204	.010102	.539	.0102
10,000	.0001	.01	.528	.0100
10,400	.00009615	.009806	.508	.0096
10,800	.00009259	.009623	.489	.0093
11,200	.00008929	.009449	.471	.0089

TABLE XXVII.—ELEMENTS OF SLOPE (*Con.*)

Giving the ratio of the head to the distance, the sine of the angle of inclination, or the value of  $s$ , and its square root, the fall in feet per mile, and the fall in 100 feet or the per cent of grade.

Slope 1 in	Sine of Slope-angle = $s$ .	$\sqrt{s}$ .	Fall in Feet per Mile.	Fall in 100 ft. or % of Grade.
11,600	.00008621	.009285	.455	.0086
12,000	.00008333	.009129	.440	.0083
12,400	.00008065	.008980	.426	.0081
12,800	.00007813	.008839	.413	.0078
13,200	.00007576	.008704	.4	.0076
13,600	.00007353	.008575	.388	.0074
14,000	.00007143	.008452	.377	.0071
14,400	.00006945	.008334	.367	.0069
14,800	.00006757	.008220	.357	.0068
15,200	.00006579	.008111	.347	.0066
15,600	.00006410	.008007	.339	.0064
16,000	.00006250	.007906	.330	.0063
16,400	.00006098	.007809	.322	.0061
16,800	.00005952	.007715	.314	.0059
17,200	.00005814	.007625	.307	.0058
17,600	.00005682	.007538	.3	.0057
18,000	.00005556	.007454	.293	.0056
18,400	.00005435	.007372	.287	.0054
18,800	.00005319	.007293	.281	.0053
19,200	.00005208	.007217	.275	.0052
19,600	.00005102	.007142	.269	.0051
20,000	.00005	.007071	.264	.0050
20,500	.00004878	.006984	.258	.0049
21,000	.00004762	.006901	.251	.0048
21,500	.00004651	.006820	.246	.0047
22,000	.00004545	.006742	.240	.0045
22,500	.00004444	.006667	.235	.0044
23,000	.00004348	.006594	.230	.0043
23,500	.00004255	.006523	.225	.0043
24,000	.00004167	.006455	.220	.0042
24,500	.00004082	.006389	.216	.0041
25,000	.00004	.006325	.211	.0040



**PART VI**

**MISCELLANEOUS AND REFERENCE  
TABLES**

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## PART VI

### MISCELLANEOUS AND REFERENCE TABLES

#### HYDRAULIC UNITS

The following hydraulic units are among those in general use throughout the United States, to wit: a Million Gallons, the Cubic Foot, the Acre-Foot and the Miner's Inch.

**The Million Gallons.** To be exact, the United States gallon of 231 cu.in. (0.13368 cu.ft.) is the technical unit, but a collective unit of one million gallons is largely used in municipal work by water-supply and sanitary engineers. A day of twenty-four hours is the time element with which it is usually incorporated to render it available as a flowage unit.

**The Cubic Foot.** This unit has a lineage that runs directly back to the International Standard Meter, and our other units are usually described as being some number of, or some fractional part of, a cubic foot. The second is in general use as a time prefix, and a second-foot is used to designate such a flow of water as will deliver one cubic foot in a second of time. The cubic foot and the second-foot are the units generally used by professional engineers and hydraulic artisans in every section of the country.

**The Acre-foot.** This unit is of recent origin, and is used principally by engineers in the irrigation and reclamation service. It contains 43,560 cu.ft., or the quantity of water required to cover an acre of land to the depth of one foot. No fixed time element has attached to the acre-foot so far as I am informed. A time suffix is generally employed to express its flowage value; to wit, an acre-foot per hour, or an acre-foot per day, as the case may require. In Table XXVIII I have used the acre-foot per day as a basis for comparing it with the other flowage units.

**The Miner's Inch** or the inch, as it is generally expressed, is of plebeian origin, having been evolved and first used by a body of men who were, perhaps above all else, intensely prac-

tical. The necessity of some device for measuring water among the early placer miners of California brought forth a variety of boxes in which the height of the opening ranged from 2 to 6 or more inches, and the head above the center of the orifice ranged from 4 to 9 or more inches. The width of the opening was usually adjustable, and the number of inches was found by multiplying the length by the height of the orifice, as measured in inches; that is, the "inches of water" was identical with the area of the orifice in square inches.

Boxes of varying proportions were adopted by the different ditch and flume companies, with the result that the quantity delivered to the consumer, as an inch of water, ranged from 1.25 to 1.75 cu.ft. per minute; but as the price was controlled by local conditions and differed even more widely than the volume delivered, the latter discrepancy was relatively a matter of small importance. Had the California water companies disposed of their commodity by the cubic foot, it is not at all likely that the volume delivered would have been in closer accord than are the North Bloomfield, the South Yuba, or the Smartsville miner's inch.

The miner's box is for excellent reasons rejected by engineers as a measuring device; and many, without reflection, have discarded the inch as a unit, together with the box. For the past thirty years I have used the inch as equivalent to 1.5 cu.ft. per minute, with a growing appreciation of its advantages as a flowage unit; not as a substitute for or to replace any other, but as a convenient and practical acquisition to our hydraulic units.

Reasons for its retention lie in the fact that it is the only unit in which the element of time is incorporated in a single word; the only unit with which we can indicate a volume of running water without the use of a hyphenated compound, which too often requires a further explanation. The inch is the only single-word unit that indicates the quantity we are to get, together with the knowledge of the time in which we are to receive it; the only unit that will, in a single word, define a volume of water in motion. Again, as an inch is but one-fortieth part of a second-foot, it is possible to express a much smaller flow without resorting to a fractional or decimal notation—an advantage that many regard as quite important, and is welcomed by all who are using small heads of running water.

Finally, the genesis of the inch is industrial; its volume is easily estimated by the layman, as the miner's box from which it was evolved is readily conceived, and similar conditions of flow are often observed in the ordinary walks of life.

Instead of discarding the inch, the profession should standardize it. Montana has legalized the second-foot as equivalent to 40 ins. On this ratio an inch is equal to 0.025 second-foot, or 1.5 cu.ft. per minute, which is very close to its mean value as used by the early miners of California, and very near the actual discharge of an inch orifice under a head of 6 ins.

In Table XXVIII the second-foot, the miner's inch as legalized in Montana, the million gallons in twenty-four hours,—if we observe the decimal, or the actual number of gallons per day if the decimal be ignored,—and the acre-foot per day have each been converted into terms of the other for a large number of graduated values between 0.0025 and 2500 ft. per second. The following factors and reciprocals, which have been used in computing this table, may be found convenient for further reductions:

	Second-feet.	Miner's inch.	Million gals.	Acre-feet.
Second-feet. ....	.....	0.025	1.547229	0.504168
Miner's inch. ....	40.0	.....	61.889142	20.166576
Million gals. ....	0.646317	0.016158	.....	0.325852
Acre-feet. ....	1.983471	0.049587	3.068882	.....

To convert from any denomination named at the head of the columns to any denomination named in the column on the left, multiply by the factor found at the intersection of the line and column.

To convert from any denomination named in the column on the left to any denomination heading the columns, divide by the factor found at the intersection of the line and column.

TABLE XXVIII

Converting second-feet, inches, million gallons, and acre-feet per day each into terms of the other three.

*Equivalents employed*

1 U. S. gal. = 231 cu.ins. = 0.133681 cu.ft.  
 1 cubic foot = 7.48052 U. S. gals.  
 1 inch = 0.025 sec.-ft. = 1.5 cu.ft. per min.  
 1 sec.-ft. = 1 cu.ft. per sec. = 40 ins.  
 1 sec.-ft. = 646.317 gallons per day.  
 1 sec.-ft. = 1.9835 acre-feet per day.  
 1 acre-ft. = 43560 cu.ft.

Sec.- feet	Miner's inches	Million gals. in 24 hrs.	Acre-ft. per day	Sec.- feet	Miner's inches	Million gals. in 24 hrs.	Acre-ft. per day
.0025	.1	.001616	.004959	.105	4.2	.067863	.20826
.0050	.2	.003232	.009917	.110	4.4	.071095	.21818
.0075	.3	.004847	.014876	.115	4.6	.074326	.22810
.0100	.4	.006463	.019835	.120	4.8	.077558	.23802
.0125	.5	.008079	.024793	.125	5.0	.080790	.24793
.0150	.6	.009695	.029752	.130	5.2	.084021	.25785
.0175	.7	.011311	.034711	.135	5.4	.087253	.26777
.0200	.8	.012926	.039669	.140	5.6	.090484	.27769
.0225	.9	.014542	.044628	.145	5.8	.093716	.28760
.0250	1.0	.016158	.049587	.150	6.0	.096948	.29752
.0275	1.1	.017774	.054545	.160	6.4	.103411	.31736
.0300	1.2	.019390	.059504	.170	6.8	.109874	.33719
.0325	1.3	.021005	.064463	.180	7.2	.116337	.35702
.0350	1.4	.022621	.069421	.190	7.6	.122800	.37686
.0375	1.5	.024237	.074380	.200	8.0	.129263	.39669
.0400	1.6	.025853	.079339	.210	8.4	.135727	.41653
.0425	1.7	.027468	.084298	.220	8.8	.142190	.43636
.0450	1.8	.029084	.089256	.230	9.2	.148653	.45620
.0475	1.9	.030700	.094215	.240	9.6	.155116	.47603
.0500	2.0	.032316	.099174	.250	10.0	.161579	.49587
.0525	2.1	.033932	.104132	.275	11.0	.177737	.54545
.0550	2.2	.035547	.109091	.300	12.0	.193895	.59504
.0575	2.3	.037162	.114050	.325	13.0	.210053	.64463
.0600	2.4	.038779	.119008	.350	14.0	.226211	.69421
.0625	2.5	.040395	.123967	.375	15.0	.242369	.74380
.0650	2.6	.042011	.128926	.400	16.0	.258527	.79339
.0675	2.7	.043626	.133884	.425	17.0	.274685	.84298
.0700	2.8	.045242	.138843	.450	18.0	.290843	.89256
.0725	2.9	.046858	.143802	.475	19.0	.307001	.94215
.0750	3.0	.048474	.148760	.500	20.0	.323159	.99174
.0775	3.1	.050090	.153719	.525	21.0	.339316	1.04132
.0800	3.2	.051705	.158678	.550	22.0	.355474	1.09091
.0825	3.3	.053321	.163636	.575	23.0	.371632	1.14050
.0850	3.4	.054937	.168595	.600	24.0	.387790	1.19008
.0875	3.5	.056553	.173554	.625	25.0	.403948	1.23967
.0900	3.6	.058169	.178512	.650	26.0	.420106	1.28926
.0925	3.7	.059784	.183471	.675	27.0	.436264	1.33884
.0950	3.8	.061400	.188430	.700	28.0	.452422	1.38843
.0975	3.9	.063016	.193388	.725	29.0	.468580	1.43802
.1000	4.0	.064632	.198348	.750	30.0	.484738	1.48761

TABLE XXVIII (Con.)

Converting second-feet, inches, million gallons, and acre-feet per day each into terms of the other three.

*Equivalents employed*

1 U. S. gal. = 231 cu.ins. = 0.133861 cu.ft.

1 cubic foot = 7.48052 U. S. gals.

1 inch = 0.025 sec.ft. = 1.5 cu.ft. per min.

1 sec.-ft. = 1 cu.ft. per sec. = 40 ins.

1 sec.-ft. = 646,317 gallons per day.

1 sec.-ft. = 1.9835 acre-feet per day.

1 acre-foot = 43,560 cu.ft.

Sec.-feet	Miner's inches	Million gals. in 24 hrs.	Acre-ft. per day	Sec.-feet	Miner's inches	Million gals. in 24 hrs.	Acre-ft. per day
.80	32	.517054	1.5868	6.50	260	4.201060	12.893
.85	34	.549369	1.6860	6.75	270	4.362639	13.388
.90	36	.581685	1.7851	7.00	280	4.524218	13.884
.95	38	.614001	1.8843	7.25	290	4.685798	14.380
1.00	40	.646317	1.9835	7.50	300	4.847377	14.876
1.05	42	.678633	2.0826	8.00	320	5.170535	15.868
1.10	44	.710949	2.1818	8.50	340	5.493694	16.860
1.15	46	.743264	2.2810	9.00	360	5.816852	17.851
1.20	48	.775580	2.3802	9.50	380	6.140011	18.843
1.25	50	.807896	2.4793	10.00	400	6.463169	19.835
1.30	52	.840212	2.5785	10.50	420	6.786328	20.826
1.35	54	.872528	2.6777	11.00	440	7.109486	21.818
1.40	56	.904844	2.7769	11.50	460	7.432645	22.810
1.45	58	.937160	2.8760	12.00	480	7.755803	23.802
1.50	60	.969475	2.9752	12.50	500	8.078962	24.793
1.60	64	1.034107	3.1736	13.00	520	8.402120	25.785
1.70	68	1.098739	3.3719	13.50	540	8.725279	26.777
1.80	72	1.163370	3.5702	14.00	560	9.048437	27.769
1.90	76	1.228002	3.7686	14.50	580	9.371595	28.760
2.00	80	1.292634	3.9669	15.00	600	9.694754	29.752
2.10	84	1.357266	4.1653	16.00	640	10.341071	31.736
2.20	88	1.421897	4.3636	17.00	680	10.987388	33.719
2.30	92	1.486529	4.5620	18.00	720	11.633705	35.702
2.40	96	1.551161	4.7603	19.00	760	12.280022	37.686
2.50	100	1.615792	4.9587	20.00	800	12.926339	39.669
2.75	110	1.777372	5.4545	21.00	840	13.572655	41.653
3.00	120	1.938951	5.9504	22.00	880	14.218972	43.636
3.25	130	2.100530	6.4463	23.00	920	14.865289	45.620
3.50	140	2.262110	6.9421	24.00	960	15.511606	47.603
3.75	150	2.423688	7.4380	25.00	1000	16.157923	49.587
4.00	160	2.585268	7.9339	27.50	1100	17.773716	54.545
4.25	170	2.746847	8.4298	30.00	1200	19.389508	59.504
4.50	180	2.908426	8.9256	32.50	1300	21.005300	64.463
4.75	190	3.070005	9.4215	35.00	1400	22.621092	69.421
5.00	200	3.231585	9.9174	37.50	1500	24.236885	74.380
5.25	210	3.393164	10.4132	40.00	1600	25.852677	79.339
5.50	220	3.554743	10.9091	42.50	1700	27.468469	84.298
5.75	230	3.716322	11.4050	45.00	1800	29.084262	89.256
6.00	240	3.877902	11.9008	47.50	1900	30.700054	94.215
6.25	250	4.039481	12.3968	50.00	2000	32.315846	99.174

TABLE XXVIII (Con.)

Converting second-feet, inches, million gallons, and acre-feet per day each into terms of the other three.

*Equivalents employed*

1 U. S. gal. = 231 cu.ins = 0.133681 cu.ft.  
 1 cubic foot = 7.48052 U. S. gals.  
 1 inch = 0.025 sec.-ft. = 1.5 cu.ft. per min.  
 1 sec.-ft. = 1 cu.ft. per sec. = 40 ins.  
 1 sec.-ft. = 646,317 gallons per day.  
 1 sec.-ft. = 1.9835 acre-feet per day.  
 1 acre-foot = 43,560 cu.ft.

Sec.-feet	Miner's inches	Million gals. in 24 hrs.	Acre-ft. per day	Sec.-feet	Miner's inches	Million gals. in 24 hrs.	Acre-ft. per day
52.5	2,100	33.931639	104.13	375	15,000	242.368848	743.80
55.0	2,200	35.547431	109.09	400	16,000	258.526771	793.39
57.5	2,300	37.163223	114.05	425	17,000	274.684694	842.98
60.0	2,400	38.779016	119.01	450	18,000	290.842618	892.56
62.5	2,500	40.394808	123.97	475	19,000	307.000541	942.15
65.0	2,600	42.010600	128.93	500	20,000	323.158464	991.74
67.5	2,700	43.626393	133.88	525	21,000	339.316387	1041.32
70.0	2,800	45.242185	138.84	550	22,000	355.474310	1090.91
72.5	2,900	46.857977	143.80	575	23,000	371.632234	1140.50
75.0	3,000	48.473770	148.76	600	24,000	387.790157	1190.08
80.0	3,200	51.705354	158.68	625	25,000	403.948080	1239.67
85.0	3,400	54.936939	168.60	650	26,000	420.106003	1289.26
90.0	3,600	58.168524	178.51	675	27,000	436.263926	1338.84
95.0	3,800	61.400108	188.43	700	28,000	452.421950	1388.43
100.0	4,000	64.631693	198.35	725	29,000	468.579773	1438.02
105.0	4,200	67.863277	208.26	750	30,000	484.737696	1487.60
110.0	4,400	71.094862	218.18	800	32,000	517.053542	1586.78
115.0	4,600	74.326447	228.10	850	34,000	549.369389	1685.95
120.0	4,800	77.558031	238.02	900	36,000	581.685235	1785.12
125.0	5,000	80.789616	247.93	950	38,000	614.001082	1884.30
130.0	5,200	84.021201	257.85	1000	40,000	646.316928	1983.47
135.0	5,400	87.252785	267.77	1050	42,000	678.632774	2082.64
140.0	5,600	90.484370	277.69	1100	44,000	710.948621	2181.82
145.0	5,800	93.715955	287.60	1150	46,000	743.264467	2280.99
150.0	6,000	96.947539	297.52	1200	48,000	775.580314	2380.17
160.0	6,400	103.410708	317.36	1250	50,000	807.896160	2479.34
170.0	6,800	109.873878	337.19	1300	52,000	840.212006	2578.51
180.0	7,200	116.337047	357.02	1350	54,000	872.527853	2677.69
190.0	7,600	122.800216	376.86	1400	56,000	904.843699	2776.86
200.0	8,000	129.263386	396.69	1450	58,000	937.159546	2876.03
210.0	8,400	135.726555	416.53	1500	60,000	969.475392	2975.21
220.0	8,800	142.189724	436.36	1625	65,000	1050.265008	3223.14
230.0	9,200	148.652893	456.20	1750	70,000	1131.054624	3471.07
240.0	9,600	155.116063	476.03	1875	75,000	1211.844240	3719.01
250.0	10,000	161.579232	495.87	2000	80,000	1292.633856	3966.94
275.0	11,000	177.737155	545.45	2125	85,000	1373.423472	4214.88
300.0	12,000	193.895078	595.04	2250	90,000	1454.213088	4462.81
325.0	13,000	210.053002	644.63	2375	95,000	1535.002704	4710.74
350.0	14,000	226.210925	694.21	2500	100,000	1615.792320	4958.68

## WEIGHT OR STATIC PRESSURE IN FLUIDS

In hydrostatics the following principles are fundamental:

First. Fluids under the influence of gravity press equally in all directions upon the walls of a containing vessel.

Second. The pressure per unit of surface is quite independent of the volume or quantity of fluid in its horizontal extension.

Third. The pressure per unit of surface is dependent upon the vertical extension of the fluid, that is, the pressure at any point is directly proportional to the head or distance below the surface.

Fourth. The pressure at any point will be exerted in a direction perpendicular to the containing wall at that point.

## EQUIVALENTS HERE USED

One cu.ft. of water = 7.48052 U. S. gals. = 1728 cu.ins.	= 62.4283 lbs.
One U. S. gal.	= 231 cu.ins. = 8.34545 lbs.
One prism 1 in. square, 1 ft. high	= 12 cu.ins. = 0.43353 lb.
One cu.in.	= 0.0361275 lb.

Head in feet  $\times .43353$  = pressure in pounds per square inch.

Head in feet  $\div 2.3066$  = pressure in pounds per square inch.

Pressure in pounds per square inch  $\times 2.3066$  = head in feet.

Pressure in pounds per square inch  $\div 0.43353$  = head in feet.

When  $H$  = head in feet, and  $P$  = pounds pressure per square inch, the foregoing ratios are expressed in the equations that follow:

$$P = 0.43353 H. \quad P = \frac{H}{2.3066}. \quad H = 2.3066 P. \quad H = \frac{P}{0.43353}.$$

For preliminary or approximate work, engineers regard the cubic foot as containing 7.5 U. S. gallons, and as weighing 62.5 lbs.; and the U. S. gallon as being 0.134 part of a cubic foot and as weighing 8.3 lbs. These values are exact enough for general use.

It matters not what the size or shape of the containing vessel may be, whether a flume, forebay, or pipe line, the static pressure at any point will depend upon its distance below the surface of the liquid. It is further obvious that any augmented pressure on the walls of an enclosing vessel will be quite independent of the *volume* added. Filling the smallest vertical tube through which water will run freely will increase the pressure upon the walls of a closed receptacle directly as the head is increased.

A pitcher of water may rend a closed vessel having great strength, or it may increase the rupturing moments of a very thin film to a surprising total if it be properly applied. A masonry dam or a concrete retaining wall, otherwise of ample proportions, may be utterly ruined if water be allowed to enter in the manner shown in Figs. 1 and 2, for the pressure at any point in an open seam will equal that against the perpendicular

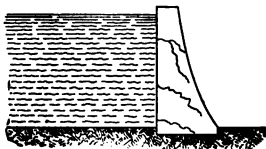


FIG. 1.

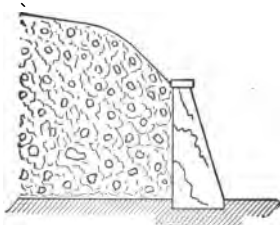


FIG. 2.

face of either wall if situated at the same distance below the water level.

On the other hand, the quantity or volume of water behind a dam is but indirectly concerned in its overthrow; as the waters of Lake Erie (disregarding wind and wave action for the

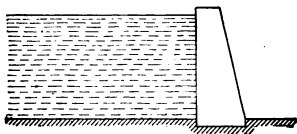


FIG. 3.

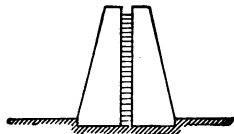


FIG. 4.

moment) are as easily controlled at the same depth as is the water on either bank of the canal of that name, while the waters of a large lake, though miles in extent, as at Fig. 3, are as easily restrained as is the narrow film shown in Fig. 4, under like conditions and at an equivalent depth below the surface.

## BUOYANCY

The floating of objects having less, and the buoyancy of objects having a greater specific gravity than that of the liquid in which they are immersed is explained by applying the principles above enunciated. Referring to the accompanying Fig. 5, we see that the sum of the moments pressing upon the lower side of the objects  $x$ ,  $y$ ,  $z$  is greater than the sum of those that are acting upon the upper side as the surfaces beneath are submerged to a greater depth. If the weight of the object is equal to the difference between the upward and the downward

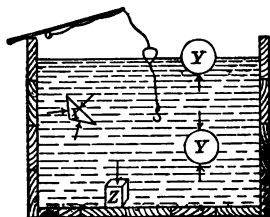


FIG. 5.

moments, no movement will occur—a condition which proves that the object and the fluid have the same specific gravity, as at  $x$  in the figure.

If the object be lighter than the liquid, the moments upon the lower side will dominate; the object will rise to the surface as at  $y$ , and float at a level at which it displaces a volume of the liquid equal to its own weight. Conversely, if the object be heavier than the liquid, it sinks to the bottom and rests there with its weight diminished by the weight of the liquid which it has displaced, as at  $z$ , in the sketch. It very often becomes a matter of prime importance to reckon with this diminished weight in submerged work.

A number of the foregoing statements may appear somewhat paradoxical, but all can be entirely reconciled by applying the fundamental principles with which the subject was introduced.

The further discussion of this and kindred topics no less important seems out of place in a handbook; but the destructive

possibilities of a thin film of water, the rapid accumulation of strains as the area is increased under an ordinary head, and the buoyant forces exerted at a modest stage of submergence, are so often matters of surprise to those who are otherwise well informed—so frequently underestimated by practical men, and not infrequently entirely overlooked and ignored by others, that some special emphasis seems warranted regarding them.

Table XXIX, which follows, will give the static pressure in pounds per square inch and in pounds per square foot, due to a large number of hydraulic heads ranging between 1 ft. and 1000 ft.

TABLE XXIX

Giving the static pressure in pounds per square inch and in pounds per square foot for a number of hydraulic heads between 1 ft. and 1000 ft.

When  $h$  = head in feet  $\left\{ \begin{array}{l} \text{pressure in lbs. per sq.in.} = 0.43353h. \\ \text{pressure in lbs. per sq.ft.} = 62.4283h. \end{array} \right.$

Head, feet	Pounds per sq.in.	Pounds per sq.ft.	Head, feet	Pounds per sq.in.	Pounds per sq.ft.
1	.4335	62.428	52	22.544	3,246.3
2	.8671	124.857	54	23.411	3,371.1
3	1.3006	187.280	56	24.278	3,496.0
4	1.7341	249.713	58	25.145	3,620.8
5	2.1677	312.142	60	26.012	3,745.7
6	2.6012	374.570	62	26.879	3,870.6
7	3.0347	436.998	64	27.746	3,995.4
8	3.4682	499.426	66	28.613	4,120.3
9	3.9018	561.855	68	29.480	4,245.1
10	4.3353	624.283	70	30.347	4,370.0
11	4.7688	686.711	72	31.214	4,494.8
12	5.2024	749.140	74	32.081	4,619.7
13	5.6359	811.568	76	32.948	4,744.6
14	6.0694	873.996	78	33.815	4,869.4
15	6.5030	936.425	80	34.682	4,994.3
16	6.9365	998.853	82	35.549	5,119.1
17	7.3700	1,061.28	84	36.417	5,244.0
18	7.8035	1,123.71	86	37.284	5,368.8
19	8.2371	1,186.14	88	38.151	5,493.7
20	8.6706	1,248.57	90	39.018	5,618.5
21	9.1041	1,310.99	92	39.885	5,743.4
22	9.5377	1,373.42	94	40.752	5,868.3
23	9.9712	1,435.85	96	41.619	5,993.1
24	10.4047	1,498.28	98	42.486	6,118.0
25	10.8383	1,560.71	100	43.353	6,242.8
26	11.272	1,623.1	105	45.521	6,555.0
27	11.705	1,685.6	110	47.688	6,867.1
28	12.139	1,748.0	115	49.856	7,179.3
29	12.572	1,810.4	120	52.024	7,491.4
30	13.006	1,872.8	125	54.191	7,803.5
31	13.439	1,935.3	130	56.359	8,115.7
32	13.873	1,997.7	135	58.527	8,427.8
33	14.307	2,060.1	140	60.694	8,740.0
34	14.740	2,122.6	145	62.862	9,052.1
35	15.174	2,185.0	150	65.030	9,364.2
36	15.607	2,247.4	155	67.197	9,676.4
37	16.041	2,309.8	160	69.365	9,988.5
38	16.474	2,372.3	165	71.532	10,300.7
39	16.908	2,434.7	170	73.700	10,612.8
40	17.341	2,497.1	175	75.868	10,925.0
41	17.775	2,559.6	180	78.035	11,237.1
42	18.208	2,622.0	185	80.203	11,549.2
43	18.642	2,684.4	190	82.371	11,861.4
44	19.075	2,746.8	195	84.538	12,173.5
45	19.509	2,809.3	200	86.706	12,485.7
46	19.942	2,871.7	205	88.874	12,797.8
47	20.376	2,934.1	210	91.041	13,109.9
48	20.809	2,996.6	215	93.209	13,422.1
49	21.243	3,059.0	220	95.377	13,734.2
50	21.677	3,121.4	225	97.544	14,046.4

TABLE XXIX (Con.)

Giving the static pressure in pounds per square inch and in pounds per square foot for a number of hydraulic heads between 1 ft. and 1000 ft.

When  $h$  = head in feet  $\left\{ \begin{array}{l} \text{pressure in lbs. per sq.in.} = 0.43353h. \\ \text{pressure in lbs. per sq.ft.} = 62.4283h. \end{array} \right.$

Head, feet	Pounds per sq.in.	Pounds per sq.ft.	Head, feet	Pounds per sq.in.	Pounds per sq.ft.
230	99.71	14,359	495	214.6	30,902
235	101.88	14,671	500	216.8	31,214
240	104.05	14,983	510	221.1	31,838
245	106.21	15,295	530	225.4	32,463
250	108.38	15,607	520	229.8	33,087
255	110.55	15,919	540	234.1	33,711
260	112.72	16,231	550	238.4	34,336
265	114.89	16,543	560	242.8	34,960
270	117.05	16,856	570	247.1	35,584
275	119.22	17,168	580	251.4	36,208
280	121.39	17,480	590	255.8	36,833
285	123.56	17,792	600	260.1	37,457
290	125.72	18,104	610	264.5	38,081
295	127.89	18,416	620	268.8	38,706
300	130.06	18,728	630	273.1	39,330
305	132.23	19,041	640	277.5	39,954
310	134.39	19,353	650	281.8	40,578
315	136.56	19,665	660	286.1	41,203
320	138.73	19,977	670	290.5	41,827
325	140.90	20,289	680	294.8	42,451
330	143.06	20,601	690	299.1	43,076
335	145.23	20,913	700	303.5	43,700
340	147.40	21,226	710	307.8	44,324
345	149.57	21,538	720	312.1	44,948
350	151.74	21,850	730	316.5	45,573
355	153.90	22,162	740	320.8	46,197
360	156.07	22,474	750	325.1	46,821
365	158.24	22,786	760	329.5	47,446
370	160.41	23,098	770	333.8	48,070
375	162.57	23,411	780	338.2	48,694
380	164.74	23,723	790	342.5	49,318
385	166.91	24,035	800	346.8	49,943
390	169.08	24,347	810	351.2	50,567
395	171.24	24,659	820	355.5	51,191
400	173.41	24,971	830	359.8	51,815
405	175.58	25,283	840	364.2	52,440
410	177.75	25,596	850	368.5	53,064
415	179.91	25,908	860	372.8	53,688
420	182.08	26,220	870	377.2	54,313
425	184.25	26,532	880	381.5	54,937
430	186.42	26,844	890	385.8	55,561
435	188.59	27,156	900	390.2	56,185
440	190.75	27,468	910	394.5	56,810
445	192.92	27,781	920	398.8	57,434
450	195.09	28,093	930	403.2	58,058
455	197.26	28,405	940	407.5	58,683
460	199.42	28,717	950	411.9	59,307
465	201.59	29,029	960	416.2	59,931
470	203.76	29,341	970	420.5	60,555
475	205.93	29,653	980	424.9	61,180
480	208.09	29,966	990	429.2	61,804
485	210.26	30,278	1000	433.5	62,428
490	212.43	30,590			

## DISCHARGE THROUGH AN ORIFICE

An innumerable variety of openings are in use for the discharge of liquids, many of which defy all efforts at classification, but a large majority may be easily recognized as falling into one of the following groups, from their manner of influencing the discharge:

First. Through thin partitions with full (natural) contraction.

Second. Through short tubes with contraction suppressed.

Third. Through partitions or tubes, formed to effect complete contraction before entering the orifice.

Fourth. Through tubes of moderate length expanded in a manner to reinforce the head and increase the flow.

It is well to note here that the terms "short" and "thin" refer to the manner in which the discharge is being effected, rather than to the actual thickness of the walls, or the length of the tubes—a distinction that will more fully appear as the action of the discharge is studied in the sketches that follow.

Those interested in such equations as are here used must accept them on faith, or consult some standard authority on the subject; it being my present purpose to review the empirical rather than the theoretical features of the subject. I aim to give the more important coefficients determined by experiment, and to aid in the selection of the value most appropriate, by refreshing the memory in a field with which the reader is already more or less familiar.

Gravity is the usual accelerating force that actuates the flow of water, and its value has been very carefully determined. The velocity that gravity imparts to a falling body in one second of time is termed "acceleration of gravity," and is designated by the letter  $g$ . It does not stand for the velocity at any particular moment, but for the velocity that accrues to a body falling in a vacuum during every second of time that it continues to fall; in short,  $g$  is a measure of the force of gravity expressed in velocity, in feet per second *per second*. Though slightly modified by the latitude and altitude of the place in

which it is measured, its numerical value as used in nearly all hydraulic computations is as follows:

- $g$  = acceleration of gravity, also the velocity in feet  
 per second at the end of the first second = 32.2  
 $\frac{1}{2}g$  = distance fallen during first second, also the  
 mean velocity during the first second = 16.1  
 $2g$  = velocity at the end of the second second, also  
 the distance fallen at end of second second = 64.4  
 $\sqrt{g}$  = a factor very frequently used in all hydraulic  
 work = 8.025  
 Let  $g$  = acceleration of gravity;  
 $v$  = the theoretical velocity in feet per second;  
 $h$  = the head, or distance below the surface in feet;  
 $t$  = the time in seconds.

Fluids under the influence of gravity obey the fundamental laws that govern a falling body, from which, among others, are derived the following hydraulic equations:

- (1)  $v = \sqrt{2gh} = gt.$   
 (2)  $h = \frac{v^2}{2g} = \frac{gt^2}{2}.$   
 (3)  $t = \frac{v}{g} = \sqrt{\frac{2h}{g}}.$   
 (4)  $g = \frac{v}{t} = 32.185$

## DISCHARGE THROUGH THIN PARTITIONS WITH FULL CONTRACTION

Fig. 6 represents an orifice through a thin plate, and an issuing stream fully or naturally contracted. As the particles approach from all directions, the impact of those reaching the orifice from the side tends to deflect a portion of those approaching on lines parallel with the axis of discharge, thus causing the jet to contract as shown at *cd*. The proportions and position of the contracted section, or *vena contracta*, have been carefully determined. Dropping decimals, that have no practical value in this connection, it is situated at one-half the diameter of the orifice from its inner face ( $ab \div 2 = ef$ ); its minimum diameter (*cd*) is 0.79, and its area 0.625 that of the orifice. The mean velocity through the minimum section under perfect conditions is given as 0.974 that of the theoretical velocity due to the head. Coefficients of discharge for a large range of openings belonging to this class have been determined—90 per cent of which fall between 0.60 and 0.63. Competent authorities name 0.61 as a suitable value for general use. A circular opening is ideal for perfect contraction, but the coefficients of discharge from



FIG. 6.

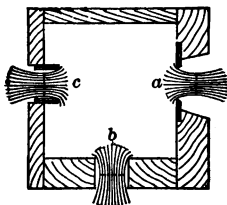


FIG. 7.

rectangular and other forms that give a symmetrical efflux do not differ greatly from those obtained from circular openings.

To insure perfect contraction, the edges of the orifice should be sharp and flush with the inner face of the receptacle (as shown at *a* and *b*, Fig. 7), and the openings should be at least one

and one-half times their smallest dimension from the surface, from the bottom, and from either wall of the containing vessel; neither should the thickness of the partition, nor the length of the tube exceed about twice the smallest dimension of the opening.

A modification of this fully contracted form of discharge appears when, instead of an orifice flush with the inner face, as at *a* and *b*, Fig. 7, a short tube of relatively thin material is projected within the reservoir a distance of about two diameters, as at *c*; the jet will still retain its contracted form, though a minimum for the coefficient of discharge may run as low as 0.51; but its value will rise gradually as the orifice is enlarged, and it will rise rapidly to 0.61 as the tube is withdrawn, or the thickness of the walls of the tube are increased with reference to its diameter.

#### DISCHARGE THROUGH SHORT TUBES WITH CONTRACTION SUPPRESSED

A discharge passes from a first- to a second-class efflux when the thickness of the containing wall, or length of the discharging tube, is increased to two and one-half or three times the diameter, or least dimension of the orifice. The distinction

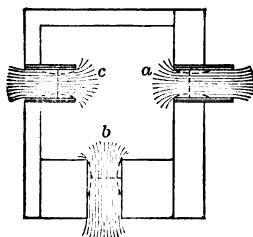


FIG. 8.

arises when the expanding jet impinges upon the outer edge of the opening, excluding the air; the tube suddenly fills with water, and contraction is suppressed, while the discharge is materially increased and settles to a steady flow. In Fig. 8 an attempt has been made to illustrate this action. Whether contraction be entirely suppressed, or to a degree only, as at *a*, *b* and *c*, the

*tendency to contract* will remain, and a partial vacuum will exist in the section where contraction would otherwise take place, as indicated by the dotted lines; when the pressure of the atmosphere on the surface of the liquid will reinforce the natural gravity head, and materially accelerate the mean velocity of issuance.

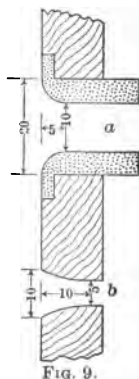
Coefficients of discharge ranging from 0.80 to 0.84 have been obtained from openings of this class, and excellent authorities suggest 0.82 as generally applicable. The change of coefficients from 0.61 to 0.82 is usually rather abrupt, and the discharge between full and suppressed contraction fitful in the extreme, while the point where the change will occur may be shifted somewhat by a change in head and other conditions too complex to follow. When the tube is extended to more than five diameters, the influence of friction becomes appreciable; the opening becomes a conduit and should be so regarded.

As in openings of the first class, a modification of this form appears when a tube of relatively thin material is projected within the reservoir, as shown at *c*, Fig. 8. Under such a condition the flow is greatly reduced, and the coefficient of discharge may be found as low as 0.71, but its value will rise gradually as the internal projection is reduced, or the thickness of the walls of the tube increased with reference to its diameter.

#### DISCHARGE THROUGH SHORT TUBES WITHOUT CONTRACTION

If an opening of either the first or second class have the corners rounded in a manner to guide the particles on easy lines as they approach the orifice, contraction is avoided, and the jet becomes a discharge of the third class. There are many forms that may be given to the opening to accomplish this purpose, but the two shown at *a* and *b*, Fig. 9, are easily formed, are quite effective, and very generally applicable. The *entrance* proper to an orifice of this character is located at the point where its minimum cross-section is attained.

Coefficients of discharge have been obtained ranging from 0.90 to 0.975 in those of perfect form; but 0.94 is usually named as a suitable mean for general use.



## DISCHARGE THROUGH EXPANDING TUBES OF MODERATE LENGTH

The mean velocity through an orifice may be increased considerably beyond the theoretical velocity due to the head, by attaching to the outer end of the opening a divergent or expanding discharge. For a discussion of the principles involved, see the later editions of Trautwine's handbook; but a brief dynamic outline of the theory is as follows:

As the particles issue from the orifice, *a*, *b*, Fig. 10, and plunge into others that are moving more quietly, their velocity is

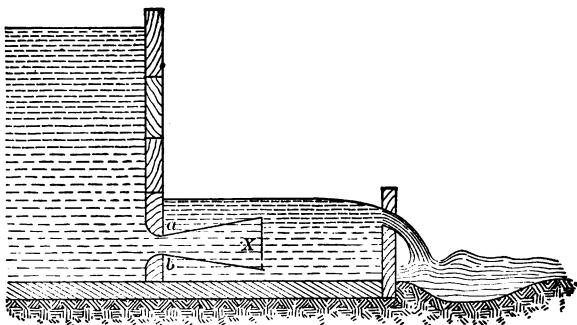


FIG. 10.

arrested by, and their momentum imparted to the liquid which occupies the expanding ajutage *X*, with a resulting *tendency* to drive this conical section from the tube. When the exit is immersed as in the figure, this cannot occur; and the action, or *tendency* to act, results in a partial vacuum in the region *a*, *b*, which reinforces the atmospheric pressure upon the surface of the liquid above the natural head to the measure of the vacuum formed, and accelerates the velocity through the orifice beyond that naturally due to the fall.

Coefficients of discharge ranging from about 0.90 to nearly 1.50 have been obtained through tubes similar to the one illustrated; but the many ratios of diameter to length, and the great variety of divergent angles, make it impracticable to name a single coefficient that would be generally applicable.

That the class of orifice and the coefficients appropriate for each may be readily found, I recapitulate as follows:

		Coeff.
First.	Through thin plates, or partitions two diameters or less in thickness, with full contraction, use	0.61
	When thin tubes project inward one or more diameters, use (modify 0.51 to 0.61 as tube is thickened or withdrawn)	0.51
Second.	Through short tubes, from two and one-half or three to five diameters, with contraction fully suppressed, use	0.82
	When thin tubes project inward one or more diameters, use (modify 0.71 to 0.82 as tube is thickened or withdrawn)	0.71
Third.	Through short tubes and orifices, less than five times the least diameter in length, with the entrance rounded or formed to prevent contraction, use	0.94
Fourth.	Through divergent tubes of moderate length, variable. Generally the discharge will be increased, but the range of conditions presented in this class precludes a choice before the entire situation is presented. Coefficients from 0.90 to 1.50 have been obtained.	

Table XXX gives the *theoretical* velocity of issuance for a number of heads ranging between 1 to 100 ins., and Table XXXI, for heads between 1 and 1000 ft. They have both been computed by the formula,  $v = \sqrt{2gh} = gt$ , (1) page 114, in which, if the numerical value of  $\sqrt{2g}$  be substituted, we obtain  $v = 8.03\sqrt{h}$ , the exact form used.

In applying the coefficients above given, and tables XXX and XXXI, to obtain velocities and discharge, observe the following

**RULE.** Multiply the theoretical, or tabular, velocity found opposite the assumed head by the coefficient of discharge given for the class to which the opening belongs, and the product will be the approximate mean velocity through the orifice in feet per second.

The discharge is obtained by multiplying the velocity thus obtained by the area of the orifice in square feet, and the product will be the approximate discharge in cubic feet per second.

TABLE XXX

Giving the *theoretical* velocities of issuance from an orifice in feet per second, for a number of graduated heads between 1 in. and 100 ins.

To obtain the approximate, *actual* mean velocity, multiply the tabular velocity found opposite the given head by the coefficient of discharge as determined by experiment for the particular class to which the opening belongs. (See page 119.)

$$(v = 8.03 \sqrt{h})$$

Head = $h$ .		$\sqrt{h}$ feet	Theoret- ical Velocity.	Head = $h$ .		$\sqrt{h}$ feet	Theoret- ical Velocity.
ins.	feet			ins.	feet		
1	.0833	.2887	2.318	30	2.5	1.581	12.695
2	.1667	.4083	3.279	31	2.583	1.607	12.904
3	.25	.5	4.015	32	2.667	1.633	13.113
4	.3333	.5773	4.636	33	2.75	1.658	13.314
5	.4167	.6455	5.183	34	2.833	1.683	13.514
6	.5	.7071	5.678	35	2.917	1.708	13.715
7	.5833	.7638	6.133	36	3.	1.732	13.908
8	.6667	.8165	6.556	38	3.167	1.780	14.293
9	.75	.8660	6.954	40	3.333	1.825	14.655
10	.8333	.9129	7.331	42	3.5	1.871	15.024
11	.9167	.9574	7.688	44	3.667	1.915	15.377
12	1.	1.	8.030	46	3.833	1.958	15.723
13	1.0833	1.041	8.359	48	4.	2.	16.060
14	1.1667	1.080	8.672	50	4.167	2.041	16.389
15	1.25	1.118	8.978	52	4.333	2.082	16.718
16	1.3333	1.155	9.275	54	4.5	2.121	17.032
17	1.4167	1.190	9.556	56	4.667	2.160	17.345
18	1.5	1.225	9.837	58	2.833	2.199	17.658
19	1.5833	1.258	10.102	60	5.	2.236	17.955
20	1.6667	1.291	10.367	64	5.333	2.309	18.541
21	1.75	1.323	10.624	68	5.667	2.381	19.119
22	1.8333	1.354	10.873	72	6.	2.449	19.665
23	1.9167	1.384	11.114	76	6.333	2.517	20.212
24	2.	1.414	11.354	80	6.667	2.582	20.733
25	2.0833	1.443	11.587	84	7.	2.646	21.247
26	2.1667	1.472	11.820	88	7.333	2.708	21.745
27	2.25	1.5	12.045	92	7.667	2.769	22.235
28	2.3333	1.528	12.270	96	8.	2.828	22.709
29	2.4167	1.555	12.487	100	8.333	2.887	23.183

TABLE XXXI

Giving the *theoretical* velocities of issuance from an orifice in feet per second, for a number of heads between 0.1 ft. and 1000 ft.

To obtain the approximate, *actual* mean velocity multiply the tabular velocity found opposite the given head by the coefficient of discharge as determined by experiment for the particular class to which the opening belongs. (See page 119.)

$$(v = 8.03 \sqrt{h})$$

$h$ feet	$\sqrt{h}$ feet	Theoretical Velocities	$h$ feet	$\sqrt{h}$ feet	Theoretical Velocities
.10	.316	2.537	10	3.162	25.39
.15	.387	3.108	11	3.317	26.64
.20	.447	3.589	12	3.464	27.82
.25	.500	4.015	13	3.606	28.96
.30	.548	4.400	14	3.742	30.05
.35	.592	4.754	15	3.873	31.10
.40	.633	5.083	16	4.000	32.12
.45	.671	5.388	17	4.123	33.11
.50	.707	5.677	18	4.243	34.07
.60	.775	6.223	19	4.359	35.00
.70	.837	6.721	20	4.472	35.91
.80	.894	7.179	21	4.583	36.80
.90	.949	7.620	22	4.690	37.66
1.00	1.000	8.030	23	4.796	38.51
1.20	1.095	8.793	24	4.899	39.34
1.40	1.183	9.499	25	5.000	40.15
1.60	1.265	10.158	26	5.099	40.94
1.80	1.342	10.776	27	5.196	41.72
2.00	1.414	11.354	28	5.292	42.49
2.25	1.500	12.045	29	5.383	43.23
2.50	1.581	12.695	30	5.477	43.98
2.75	1.658	13.314	31	5.568	44.71
3.00	1.732	13.908	32	5.657	45.43
3.25	1.803	14.478	33	5.745	46.13
3.50	1.871	15.024	34	5.831	46.82
3.75	1.936	15.546	35	5.916	47.51
4.00	2.000	16.060	36	6.000	48.18
4.25	2.061	16.550	37	6.083	48.85
4.50	2.121	17.032	38	6.184	49.66
4.75	2.179	17.497	39	6.245	50.15
5.00	2.236	17.955	40	6.325	50.79
5.50	2.345	18.830	41	6.403	51.42
6.00	2.449	19.665	42	6.481	52.04
6.50	2.550	20.477	43	6.557	52.65
7.00	2.646	21.247	44	6.633	53.26
7.50	2.739	21.994	45	6.708	53.87
8.00	2.828	22.709	46	6.782	54.46
8.50	2.915	23.407	47	6.856	55.05
9.00	3.000	24.090	48	6.928	55.63
9.50	3.082	24.748	49	7.000	56.21

TABLE XXXI (Con.)

Giving the *theoretical* velocities of issuance from an orifice in feet per second, for a number of heads between 0.1 ft. and 1000 ft.

To obtain the approximate, *actual* mean velocity multiply the tabular velocity found opposite the given head by the coefficient of discharge as determined by experiment for the particular class to which the opening belongs. (See page 119.)

$$(v = 8.03 \sqrt{h})$$

h feet	$\sqrt{h}$ feet	Theoretical Velocities	h feet	$\sqrt{h}$ feet	Theoretical Velocities
50	7.071	56.78	175	13.229	106.2
52	7.211	57.90	180	13.417	107.7
54	7.348	59.00	185	13.601	109.2
56	7.483	60.09	190	13.784	110.7
58	7.616	61.16	195	13.964	112.1
60	7.746	62.20	200	14.142	113.6
62	7.874	63.23	210	14.491	116.4
64	8.000	64.24	220	14.832	119.1
66	8.124	65.24	230	15.166	121.8
68	8.246	66.22	240	15.492	124.4
70	8.367	67.19	250	15.811	127.0
72	8.485	68.13	260	16.125	129.5
74	8.602	69.07	270	16.432	131.9
76	8.718	70.01	280	16.733	134.4
78	8.832	70.92	290	17.029	136.7
80	8.944	71.82	300	17.320	139.1
82	9.055	72.71	320	17.889	143.6
84	9.165	73.59	340	18.439	148.1
86	9.274	74.47	360	18.974	152.4
88	9.380	75.32	380	19.494	156.5
90	9.487	76.18	400	20.000	160.6
92	9.592	77.02	420	20.494	164.6
94	9.695	77.85	440	20.976	168.4
96	9.798	78.68	460	21.448	172.2
98	9.899	79.49	480	21.909	175.9
100	10.000	80.30	500	22.361	179.6
105	10.247	82.28	525	22.913	184.0
110	10.488	84.22	550	23.452	188.3
115	10.724	86.11	575	23.979	192.6
120	10.954	87.96	600	24.495	196.7
125	11.180	89.78	625	25.000	200.8
130	11.402	91.56	650	25.495	204.7
135	11.619	93.30	675	25.981	208.6
140	11.832	95.01	700	26.458	212.5
145	12.042	96.70	725	26.926	216.2
150	12.247	98.34	750	27.386	219.9
155	12.450	99.97	800	28.284	227.1
160	12.649	101.57	850	29.155	234.1
165	12.845	103.15	900	30.000	240.9
170	13.038	104.70	1000	31.623	253.9

## THE MEASUREMENT OF WATER

Only such methods as are well known and generally applicable to canal, flume, and open-channel measurements will be considered. It will be assumed that the reader is so familiar with the details of such work and the principles involved that a brief review will serve to revive the entire subject.

## GAUGING THE DISCHARGE OF A RIVER OR CANAL

When the flow in a canal or the discharge of a stream is to be measured, select a straight course with an even section and as smooth a bottom as possible, of sufficient length, when floats are to be used, to secure an accurate rating of their velocity. Cross-section the channel at one or more points and divide, by means of stakes or other markers, into as many sections as its form may indicate is necessary for estimating closely the area of each individual section.

Then with a current meter, with Pitot's tubes or other device suitable for the purpose, read the velocity at as many points as are needed to secure a mean in each section. The mean velocity in feet per second, multiplied by the area in square feet, will give the discharge of that section in second-feet; and the sum of the flow from the various sections will be the aggregate discharge of the stream.

In the absence of instruments for obtaining current velocities, a fair approximation to the mean may usually be secured by timing floats over a distance measured along the bank, and multiplying the results by a coefficient which experiments have determined as appropriate for the character of channel under examination. The method is crude, but on reconnoissance work it is often the only practical manner of proceeding with the appliances at hand.

The ratio between the maximum and mean velocities varies greatly as the size and roughness of a channel change, and practically the coefficients cannot possess the degree of refinement that their tabulation suggests; but the following arrangement will assist in classifying a channel, and in selecting an appropriate coefficient.

### COEFFICIENTS FOR REDUCING MAXIMUM SURFACE TO MEAN VELOCITIES

First.	In artificial channels 8 ft. or more, and in natural channels 12 ft. or more in depth, whose width is from two to four times their depth, with even cross-section and smooth bottom, the mean will often be found very close to the greatest surface velocity. As a safe coefficient, use	0.90
Second.	When the width is between four and eight times the depth, or when conditions are less favorable, use	0.85
Third.	Generally in natural channels with an even bottom, 0.80 is used; indeed this value more often than any other will, under usual conditions, be the one to use.	0.80
Fourth	With an uneven bottom, with depth less than one-tenth the width, or with a variable cross-section, use	0.70
Fifth.	When all of the last-named conditions are present, or others equally unfavorable, use	0.60
Finally.	As the retarding influences become more pronounced, the value of a coefficient for estimating a true mean becomes very slight.	

In general, a large or even cross-section, a smooth bottom, a straight course, a ratio of depth one-half the width, and artificial rather than natural channels, are conditions that tend to raise the mean with reference to the maximum surface velocity.

From what has been said regarding the discharge of water through orifices of various forms, it would appear that under favorable conditions almost any opening may be used to estimate the flow; and if formed in thin partitions, most of them will indicate the discharge with considerable accuracy. If an orifice be raised until its upper edge is above the surface of the liquid, the opening is termed a weir, and becomes, when carefully constructed and intelligently used, our most satisfactory appliance for small open-channel measurements.

#### WEIR GAUGING OF THE FLOW

In theory, a weir determination consists in bringing the water, without appreciable velocity, to the face of an orifice devised to reduce friction to a minimum; when, under the influence of gravity alone, it falls through the opening in a constant volume from hour to hour and from day to day, so long as the depth over the crest remains unchanged.

Let  $Q$  = actual discharge over a weir in cubic feet per second;  
 $Q'$  = theoretical discharge over a weir in cubic feet per second;  
 $V$  = the actual mean velocity in feet per second;  
 $V'$  = the theoretical velocity in feet per second;  
 $L$  = length of the weir in feet;  
 $H$  = head, or vertical distance from crest of weir to the level of quiet water above in feet;  
 $c$  = coefficient of discharge.

The mean theoretical velocity of issuance through an orifice under any head is thus expressed,

$$V' = \sqrt{2gH}, \text{ (see page 114).} \quad . \quad . \quad . \quad . \quad (5)$$

The mean theoretical velocity of water passing over a weir is thus expressed,

$$V' = \frac{2}{3}\sqrt{2gH}. \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The theoretical discharge,

$$Q' = \frac{2}{3}\sqrt{2gH} \times H \times L. \quad . \quad . \quad . \quad . \quad (7)$$

But to obtain the actual discharge, the theoretical flow is multiplied by a coefficient of discharge as determined by experiment, and is expressed,

$$Q = c \times \frac{2}{3}\sqrt{2gH} \times H \times L. \quad . \quad . \quad . \quad . \quad (8)$$

The value of  $c$  for rectangular weirs as determined by Francis' experiments is 0.622, while  $\sqrt{2g} = 8.025$  and  $\frac{2}{3}\sqrt{2g} = 5.35$ . Substituting these values and reducing, we obtain for the actual discharge of a rectangular weir, disregarding for the moment the influence of end contractions,

$$Q = 3.33\sqrt{H} \times H \times L. \quad . \quad . \quad . \quad . \quad (9)$$

Following Francis' suggestion to subtract one-tenth of the head from the length, for each end contraction, we obtain for an ordinary weir with two end contractions,

$$Q = 3.33\sqrt{H} \times H \times \left(L - \frac{H}{5}\right) \quad . \quad . \quad . \quad (10)$$

If in the formula (9)  $L$  be made equal to one, we obtain a form for the actual discharge over a unit length of weir (one foot) without end contraction as follows:

$$Q = 3.33\sqrt{H} \times H = 3.33H^{\frac{3}{2}}. \quad . \quad . \quad . \quad (11)$$

Turning from the foregoing brief statement of the theory, let us examine a few of the many mechanical appliances that have been proposed, or are now in use, for measuring the flow in ditches, canals, and open channels of moderate capacity.

### THE MINER'S BOX

I have spoken of the miner's box as having been discarded by engineers; but in its day this contrivance answered every requirement among the miners of California. One form which was in general use is shown in Fig. 11. Used as a weir under any circumstances, its merit is questionable; but the broad hiatus between the maximum and minimum miner's inch was caused more by the variations of head in vogue rather than by any inherent defect in the box. As the price charged by the water companies was fixed by local conditions rather than by quantity

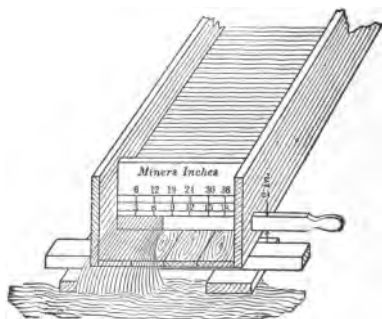


FIG. 11.

delivered, the various boxes answered every purpose. It is not offered here because of any merit as a weir, but as an interesting hydraulic relic from a day that has passed and gone.

### RECTANGULAR WEIRS

In general to insure its proper action, the crest of a weir must be level, its face plumb, the banks and bottom tamped till water tight, and all secured in a manner precluding vibration. To insure complete contraction, the distance from the end of the orifice to either bank, or from the crest level to the bottom of the channel, should not be less than one and one-half times the

head. (See *a*, Fig. 12.) To reduce the velocity of approach, the channel should have a wet cross-sectional area at east six times the wet area at the crest, for a distance above the opening of about ten times the head; and if at that point the current velocity is still high, its momentum should be killed by placing baffle boards or other obstructions across the channel. The openings should be formed in thin plates, or have their margins chamfered to a feather edge (as shown at *b* and *c*), and there must be sufficient grade in the channel below to remove the tail water and give the air free access for thoroughly ventilating the under side of the effluent stream.

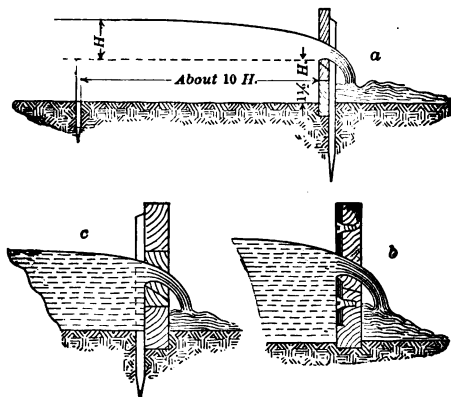


FIG. 12.

#### RECTANGULAR WEIRS WITHOUT END CONTRACTIONS

In measuring a moderate flow, the most exact results can probably be obtained by using a form, having complete bottom but no end contractions. (See *a* and *b*, Fig. 13.) The side pieces should be extended far enough below and beyond the crest, and far enough up stream to prevent any tendency to contract at the ends, with the bottom at least one and one-half times the head below the crest, to insure perfect contraction from below. It is recommended that the bottom be at least twice the head below the crest when practicable, as the velocity of approach is thereby further reduced. This form is easily

placed for gauging the flow in timber flumes and other rectangular channels, when the grade is sufficient to warrant such action; but when so used it becomes quite essential that the space below the falling sheet be thoroughly ventilated.

#### ORDINARY RECTANGULAR WEIRS WITH END CONTRACTIONS

As the volume to be measured is increased, a preference is given to the rectangular weir with two-end contractions (see Fig. 14), as it is cheaper, and requires less expert assistance in setting than the other forms here given. Something very

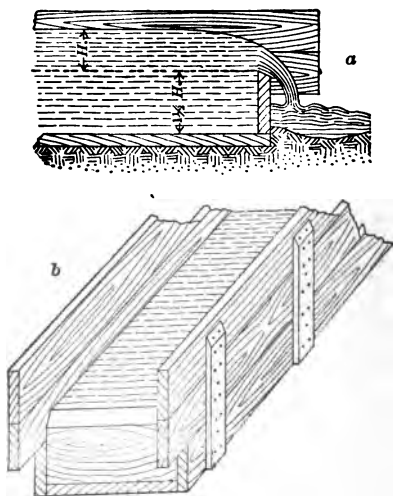


FIG. 13.

similar to the illustration is generally used in open-channel measurements, and is the invariable first aid in all preliminary work.

The practical effect of an end contraction is to shorten the length of the weir. Francis corrects by subtracting one-tenth of the head from the length of the weir for each end contraction; one-fifth of the head from the length of the ordinary opening with two end contractions. (See formula 10, page 125). In this connection, he further observes that when the

length of the crest is ten or more times the head, the relative effect of end contractions becomes so slight that they may be neglected without seriously affecting the result; while, upon the other hand, if the length be less than three times the head, the contractions dominate to an extent that renders the results somewhat questionable.

### THE CIPPOLETTI WEIR

The trapezoidal opening introduced by Cesare Cippoletti, an eminent Italian engineer (see Fig. 15), reverses Francis' method; and, instead of subtracting, adds to the length as the head increases to correct for end contractions. This result is attained by inclining the ends of the opening outward from the crest at an angle of  $14^{\circ} 29'$  from the perpendicular; that is, the

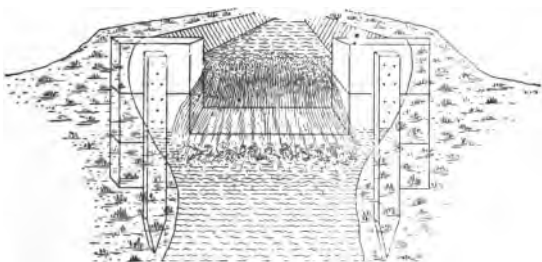


FIG. 14.

ends are given a slope of one horizontal to four perpendicular (as shown in the figure), when the increased length of surface flow as the water rises above the crest automatically compensates for its increased tendency to contract, and the working length of the weir remains unchanged for any head.

The direct simplicity of this device is a strong recommendation, and it should be regarded with special favor by all who find the repeated corrections in length, at every change in head, an irksome task.

Table XXXII may be used for obtaining the flow through any of the weirs above described; not failing, of course, in case there are end contractions, to make the necessary corrections in length.

The table gives the actual discharge in cubic feet per second

and in miner's inches, for each foot in length of weir for a number of heads ranging from  $\frac{1}{4}$  of an inch to 60 ins. I have used the Francis formula, giving to his coefficient  $c$  a value of 0.622. He cautions us about using his results very far beyond the range of his experiments, which for the most part were performed with heads ranging between 7 and 19 ins. Other experiments have confirmed his results for heads above 19 ins.; but the reader should be doubly cautious as either the upper or lower limits of the table here presented is reached.

**RULE.** Multiply the tabular discharge found opposite the head that lies nearest to the one given or assumed, by the

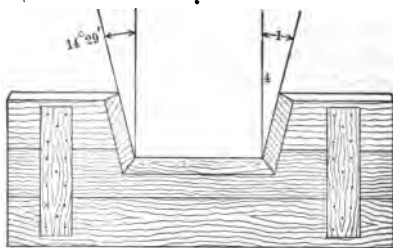


FIG. 15.

corrected length of crest in feet, if there be end contractions, or by the actual length if there be no end contractions, and the product will be the approximate discharge in cubic feet per second.

*Example.* What discharge, with two end contractions, length 9.94, head 0.96 ft.?

*Solution.* We have  $9.94 - \frac{.96}{5} = 9.748$  corrected crest length.

In table XXXII, line 65, we find opposite .9583 (nearest head) a discharge of 3.124 sec.-ft. Whence,  $9.748 \times 3.124 = 30.45$  as the approximate discharge in cubic feet per second, or  $9.748 \times 124.95 = 1218$  as the approximate discharge in inches.

TABLE XXXII

Giving discharge in inches and in cubic feet per second for each foot in length of weir through thin plates without end contraction, by the Francis formula.

$$Q = 3.33H\sqrt{H}.$$

No.	Head.		Discharge.		No.	Head.		Discharge.	
	ins.	feet	sec.-ft.	Mins. ins.		ins.	feet	sec.-ft.	Mins. ins.
1	$\frac{1}{4}$	.0208	.0100	.400	41	$5\frac{1}{4}$	.4583	1.033	41.33
2	$\frac{3}{8}$	.0313	.0184	.738	42	$\frac{3}{4}$	.4792	1.105	44.18
3	$\frac{1}{2}$	.0417	.0284	1.134	43	6	.5000	1.177	47.09
4	$\frac{5}{8}$	.0521	.0396	1.584	44	$\frac{1}{4}$	.5208	1.252	50.06
5	$\frac{3}{4}$	.0625	.0520	2.081	45	$\frac{1}{2}$	.5417	1.328	53.11
6	$\frac{7}{8}$	.0729	.0655	2.622	46	$\frac{3}{4}$	.5625	1.405	56.19
7	1	.0833	.0801	3.202	47	7	.5833	1.483	59.34
8	$\frac{1}{8}$	.0938	.0957	3.827	48	$\frac{1}{4}$	.6042	1.564	62.56
9	$\frac{1}{4}$	.1042	.1120	4.480	49	$\frac{1}{2}$	.6250	1.645	65.82
10	$\frac{3}{8}$	.1146	.1292	5.167	50	$\frac{3}{4}$	.6458	1.728	69.13
11	$\frac{1}{2}$	.1250	.1472	5.887	51	8	.6667	1.813	72.51
12	$\frac{5}{8}$	.1354	.1659	6.637	52	$\frac{1}{4}$	.6875	1.898	75.93
13	$\frac{3}{4}$	.1458	.1854	7.417	53	$\frac{1}{2}$	.7083	1.985	79.40
14	$\frac{7}{8}$	.1563	.2058	8.232	54	$\frac{3}{4}$	.7292	2.073	82.94
15	2	.1667	.2267	9.066	55	9	.7500	2.163	86.51
16	$\frac{1}{8}$	.1771	.2482	9.927	56	$\frac{1}{4}$	.7708	2.254	90.14
17	$\frac{1}{4}$	.1875	.2704	10.814	57	$\frac{1}{2}$	.7917	2.346	93.82
18	$\frac{3}{8}$	.1979	.2932	11.728	58	$\frac{3}{4}$	.8125	2.439	97.55
19	$\frac{1}{2}$	.2083	.3166	12.663	59	10	.8333	2.533	101.33
20	$\frac{5}{8}$	.2188	.3408	13.634	60	$\frac{1}{4}$	.8542	2.629	105.15
21	$\frac{3}{4}$	.2292	.3654	14.614	61	$\frac{1}{2}$	.8750	2.726	109.02
22	$\frac{7}{8}$	.2396	.3906	15.622	62	$\frac{3}{4}$	.8958	2.823	112.94
23	3	.2500	.4163	16.650	63	11	.9167	2.923	116.90
24	$\frac{1}{8}$	.2604	.4425	17.700	64	$\frac{1}{4}$	.9375	3.023	120.90
25	$\frac{1}{4}$	.2708	.4693	18.771	65	$\frac{1}{2}$	.9583	3.124	124.95
26	$\frac{3}{8}$	.2813	.4968	19.874	66	$\frac{3}{4}$	.9792	3.227	129.06
27	$\frac{1}{2}$	.2917	.5246	20.985	67	12	1.000	3.330	133.20
28	$\frac{5}{8}$	.3021	.5529	22.116	68	$\frac{1}{4}$	1.021	3.434	137.36
29	$\frac{3}{4}$	.3125	.5817	23.268	69	$\frac{1}{2}$	1.042	3.543	141.71
30	$\frac{7}{8}$	.3229	.6110	24.438	70	$\frac{3}{4}$	1.063	3.650	145.98
31	4	.3333	.6407	25.630	71	13	1.083	3.754	150.17
32	$\frac{1}{8}$	.3438	.6713	26.854	72	$\frac{1}{4}$	1.104	3.864	154.55
33	$\frac{1}{4}$	.3542	.7020	28.081	73	$\frac{1}{2}$	1.125	3.975	158.99
34	$\frac{3}{8}$	.3646	.7331	29.323	74	$\frac{3}{4}$	1.146	4.087	163.49
35	$\frac{1}{2}$	.3750	.7647	30.589	75	14	1.167	4.197	167.88
36	$\frac{5}{8}$	.3854	.7967	31.869	76	$\frac{1}{4}$	1.187	4.308	172.34
37	$\frac{3}{4}$	.3958	.8292	33.166	77	$\frac{1}{2}$	1.208	4.421	176.84
38	$\frac{7}{8}$	.4063	.8624	34.496	78	$\frac{3}{4}$	1.229	4.539	181.55
39	5	.4167	.8957	35.828	79	15	1.250	4.654	186.16
40	$\frac{1}{4}$	.4375	.9636	38.544	80	$\frac{1}{2}$	1.271	4.770	190.80

TABLE XXXII (Con.)

Giving discharge in inches and in cubic feet per second for each foot in length of weir through thin plates without end contraction, by the Francis formula.

$$Q = 3.33H\sqrt{H}.$$

No.	Head.		Discharge.		No.	Head.		Discharge.	
	ins.	feet	sec.-ft.	Mins. ins.		ins.	feet	sec.-ft.	Mins. ins.
81	1½	1.292	4.892	195.7	121	27	2.250	11.24	450
82	1¾	1.333	5.011	200.4	122	28	2.292	11.56	462
83	16	1.353	5.127	205.1	123	28	2.333	11.86	475
84	1¾	1.354	5.248	209.9	124	28	2.375	12.19	488
85	1½	1.375	5.371	214.8	125	29	2.416	12.50	500
86	3¼	1.396	5.495	219.8	126	29	2.458	12.83	513
87	17	1.417	5.615	224.6	127	30	2.500	13.16	526
88	1¾	1.437	5.737	229.5	128	30	2.542	13.49	540
89	1¾	1.458	5.860	234.4	129	31	2.583	13.82	553
90	3¼	1.479	5.989	239.6	130	31	2.625	14.16	566
91	18	1.500	6.119	244.8	131	32	2.666	14.50	580
92	1¾	1.521	6.245	249.8	132	32	2.708	14.84	594
93	1½	1.542	6.377	255.1	133	33	2.750	15.18	607
94	3¼	1.563	6.506	260.2	134	33	2.792	15.54	621
95	19	1.583	6.631	265.3	135	34	2.833	15.88	635
96	1¾	1.604	6.762	270.5	136	34	2.875	16.24	649
97	1½	1.625	6.899	276.0	137	35	2.917	16.59	664
98	3¼	1.646	7.032	281.3	138	35	2.958	16.94	678
99	20	1.667	7.166	286.7	139	36	3.000	17.30	692
100	1¾	1.688	7.302	292.1	140	37	3.083	18.03	721
101	1½	1.708	7.434	297.3	141	38	3.167	18.77	751
102	3¼	1.729	7.571	302.8	142	39	3.250	19.51	781
103	21	1.750	7.710	308.4	143	40	3.333	20.27	811
104	1¾	1.771	7.849	314.0	144	41	3.417	21.04	842
105	1½	1.792	7.990	319.6	145	42	3.500	21.81	872
106	3¼	1.813	8.126	325.0	146	43	3.583	22.59	903
107	22	1.833	8.265	330.6	147	44	3.666	23.38	935
108	1¾	1.854	8.409	336.4	148	45	3.750	24.18	967
109	1½	1.875	8.548	341.9	149	46	3.833	24.99	1000
110	3¼	1.896	8.694	347.8	150	47	3.917	25.81	1033
111	23	1.917	8.841	353.7	151	48	4.000	26.64	1066
112	1¾	1.938	8.983	359.3	152	50	4.167	28.32	1133
113	1½	1.958	9.122	364.9	153	52	4.333	30.04	1202
114	3¼	1.979	9.272	370.9	154	54	4.500	31.78	1271
115	24	2.000	9.417	376.7	155	56	4.667	33.57	1343
116	1½	2.042	9.717	388.7	156	58	4.833	35.37	1415
117	25	2.083	10.009	400.4	157	60	5.000	37.23	1489
118	1½	2.125	10.317	412.7					
119	26	2.167	10.623	424.9					
120	1½	2.208	10.926	437.0					

## THE VEE NOTCH (V), OR TRIANGULAR WEIR

The vee notch seems especially adapted to the measurement of small heads; as complete contraction on the upper, and perfect ventilation on the lower face, may be secured with less depth below the bottom of the orifice than in most other forms, while the head remains large in proportion to the volume discharged. It is claimed for this type that the top and side contractions, the air and water perimeters, all bear a constant ratio to one another; that the discharge is a function of one variable only, that of the head; and that, as the areas of discharge for the varying heads are similar triangles, the value of  $c$  remains constant at any head. These features, when combined with its cheapness, simplicity, and efficiency, form a strong aggregation in favor of this type.

Though possibly as well adapted, in theory, for measurements upon a large scale, mechanical difficulties multiply rapidly as the size or number of the triangular openings required for a gauging increase, and the rectangular form is soon to be preferred as the volume to be measured becomes larger.

The formulas used in calculating tables XXXIII and XXXIV are derived from a general equation evolved from the experiments of Prof. James Thompson of the University of Glasgow, given in the eighteenth edition of Trautwine's handbook, page 559, as follows:  $Q = 4.28mT\sqrt{h^5}$ , in which  $m$  equals the coefficient of discharge (here used as 0.615), and  $T$  equals the tangent of one-half the angle of the notch. As both the inch and the foot are in general use for measuring low heads of this character, I have used them both in the tables, and have reduced the formula to equations that may be applied directly to the head, expressed in either feet or inches.

## THE QUADRANTAL VEE NOTCH

The quadrantal weir consists of a triangular opening standing erect upon its apex, with its sides chamfered to a thin edge so disposed as to include an angle of  $90^\circ$ , as shown in Fig. 16. Probably this form of vee is more generally used than any other, and usually with entire satisfaction. To obtain the flow, we multiply the square root of the fifth power of the head by a constant that will give the discharge in cubic feet per second.

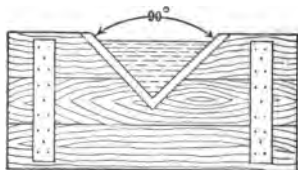


FIG. 16.

The two formulas that have been used in computing Table XXXIII are as follows:

First. When the head is given in feet,

$$Q = 2.6322\sqrt{h^5} \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Second. When the head is given in inches,

$$Q = .005277\sqrt{h^5} \quad . \quad . \quad . \quad . \quad . \quad (13)$$

*Example.* What will be the flow through a quadrantal weir under a head of  $6\frac{3}{4}$  ins. (0.531 ft.)?

When the head is given in feet,  $0.531^5 = .042215565$ , and  $\sqrt{.042215565} = .205464 \times 2.6322 = .5408 =$  the discharge in second-feet.

When the head is given in inches ( $6\frac{3}{4} = 6.375$  ins.)  $6.375^5 = 10529.322109$  and  $\sqrt{10529.322109} = 102.6125 \times .005277 = .5415$ , the discharge in second-feet.

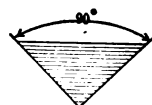
Proportioning from the nearest value in the table, we find it in substantial accord with either result.

TABLE XXXIII

Giving discharge in cubic feet per second for a  
quadrantal weir.

With the head in feet,  $Q = 2.6322h^{\frac{3}{2}}$ ;

with the head in inches,  $Q = .005277h^{\frac{3}{2}}$ .



No.	Head.		Discharge.	No.	Head.		Discharge.
	ins.	feet			ins.	feet	
1	$\frac{1}{4}$	.0208	.0002	46	$11\frac{1}{2}$	.9583	2.366
2	$\frac{1}{2}$	.0417	.0009	47	$\frac{3}{4}$	.9792	2.497
3	$\frac{3}{4}$	.0625	.0026	48	12	1.000	2.632
4	1	.0833	.0053	49	$\frac{1}{4}$	1.021	2.772
5	$\frac{1}{4}$	.1042	.0092	50	$\frac{1}{2}$	1.042	2.916
6	$\frac{1}{2}$	.1250	.0145	51	$\frac{3}{4}$	1.063	3.067
7	$\frac{3}{4}$	.1458	.0214	52	13	1.083	3.214
8	2	.1667	.0299	53	$\frac{1}{4}$	1.104	3.372
9	$\frac{1}{4}$	.1875	.0401	54	$\frac{1}{2}$	1.125	3.532
10	$\frac{1}{2}$	.2083	.0522	55	$\frac{3}{4}$	1.146	3.701
11	$\frac{3}{4}$	.2292	.0662	56	14	1.167	3.872
12	3	.2500	.0823	57	$\frac{1}{4}$	1.187	4.040
13	$\frac{1}{4}$	.2708	.1004	58	$\frac{1}{2}$	1.208	4.222
14	$\frac{1}{2}$	.2917	.1210	59	$\frac{3}{4}$	1.229	4.406
15	$\frac{3}{4}$	.3125	.1437	60	15	1.250	4.598
16	4	.3333	.1688	61	$\frac{1}{2}$	1.292	4.993
17	$\frac{1}{4}$	.3542	.1965	62	16	1.333	5.401
18	$\frac{1}{2}$	.3750	.2267	63	$\frac{3}{4}$	1.375	5.836
19	$\frac{3}{4}$	.3958	.2594	64	17	1.417	6.291
20	5	.4167	.2951	65	$\frac{1}{2}$	1.458	6.757
21	$\frac{1}{4}$	.4375	.3332	66	18	1.500	7.254
22	$\frac{1}{2}$	.4583	.3743	67	$\frac{3}{4}$	1.542	7.773
23	$\frac{3}{4}$	.4792	.4185	68	19	1.583	8.299
24	6	.5000	.4654	69	$\frac{1}{2}$	1.625	8.860
25	$\frac{1}{4}$	.5208	.5151	70	20	1.667	9.444
26	$\frac{1}{2}$	.5417	.5686	71	$\frac{3}{4}$	1.708	10.037
27	$\frac{3}{4}$	.5625	.6246	72	21	1.750	10.663
28	7	.5833	.6841	73	$\frac{1}{2}$	1.792	11.316
29	$\frac{1}{4}$	.6042	.7470	74	22	1.833	11.974
30	$\frac{1}{2}$	.6250	.8128	75	$\frac{3}{4}$	1.875	12.671
31	$\frac{3}{4}$	.6458	.8823	76	23	1.917	13.393
32	8	.6667	.9552	77	$\frac{1}{2}$	1.958	14.122
33	$\frac{1}{4}$	.6875	1.0316	78	24	2.000	14.890
34	$\frac{1}{2}$	.7083	1.1113	79	25	2.083	16.483
35	$\frac{3}{4}$	.7292	1.1953	80	26	2.167	18.196
36	9	.7500	1.2821	81	27	2.250	19.990
37	$\frac{1}{4}$	.7708	1.3732	82	28	2.333	21.884
38	$\frac{1}{2}$	.7917	1.4680	83	29	2.417	23.906
39	$\frac{3}{4}$	.8125	1.5664	84	30	2.500	26.011
40	10	.8333	1.6686	85	31	2.583	28.225
41	$\frac{1}{4}$	.8542	1.7752	86	32	2.667	30.576
42	$\frac{1}{2}$	.8750	1.8852	87	33	2.750	33.010
43	$\frac{3}{4}$	.8958	1.9992	88	34	2.833	35.558
44	11	.9167	2.1179	89	35	2.917	38.251
45	$\frac{1}{4}$	.9375	2.2400	90	36	3.000	41.031

### THE EQUILATERAL VEE NOTCH

This is another form of notch that is often used, and seems eminently practical, for the reason that the angle may be accurately laid off with a pencil and straightedge, and because the head is still further increased with reference to the discharge. An elevation of this type is shown in Fig. 17, where it appears that the distance across the top and the two sides are all of

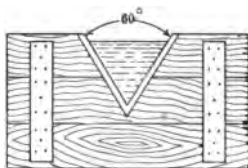


FIG. 17.

equal length, and the two chamfered sides embrace an angle of  $60^\circ$ .

The two formulas for the discharge, both used in computing table XXXIV, are as follows:

First. When the head is given in feet,

$$Q = 1.5197\sqrt{h^5} \quad \dots \dots \dots (14)$$

Second. When the head is given in inches,

$$Q = 0.003047\sqrt{h^5} \quad \dots \dots \dots (15)$$

Taking the example just computed by the quadrantal equations:

*Example.* What will be the flow through an equilateral weir under a head of  $6\frac{1}{2}$  ins. (0.531 ft.)?

When the head is given in feet,  $0.531^{\frac{5}{2}} = 0.205464 \times 1.5197 = 0.3122$ , the discharge in second-feet.

When the head is given in inches,  $6.375^{\frac{5}{2}} = 102.6125 \times 0.003047 = 0.3127$ , the discharge in second-feet.

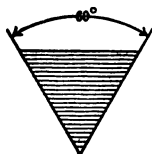
Proportions from the nearest values found in the table will be found in substantial accord.

TABLE XXXIV

Giving discharge in cubic feet per second for an equilateral weir.

With the head in feet,  $Q = 1.5197h^{3/2}$ ;

with the head in inches,  $Q = .003047h^{3/2}$ .



No.	Head.		Discharge. sec.-feet	No.	Head.		Discharge. sec.-feet
	ins.	feet			ins.	feet	
1	$\frac{1}{8}$	.0208	.0001	46	$11\frac{1}{2}$	.958	1.366
2	$\frac{1}{4}$	.0417	.0005	47	$11\frac{3}{4}$	.979	1.442
3	$\frac{3}{8}$	.0625	.0015	48	12	1.000	1.520
4	$1$	.0833	.0030	49	$12\frac{1}{4}$	1.021	1.600
5	$1\frac{1}{8}$	.1042	.0053	50	$12\frac{1}{2}$	1.042	1.684
6	$1\frac{1}{4}$	.1250	.0084	51	$12\frac{3}{4}$	1.063	1.770
7	$1\frac{3}{8}$	.1458	.0123	52	13	1.083	1.856
8	$1\frac{1}{2}$	.1667	.0172	53	$13\frac{1}{4}$	1.104	1.947
9	$1\frac{3}{4}$	.1875	.0231	54	$13\frac{1}{2}$	1.125	2.039
10	$1\frac{7}{8}$	.2083	.0301	55	$13\frac{3}{4}$	1.146	2.137
11	$2$	.2292	.0382	56	14	1.167	2.235
12	$2\frac{1}{8}$	.2500	.0475	57	$14\frac{1}{4}$	1.187	2.333
13	$2\frac{1}{4}$	.2708	.0580	58	$14\frac{1}{2}$	1.208	2.438
14	$2\frac{3}{8}$	.2917	.0698	59	$14\frac{3}{4}$	1.229	2.544
15	$2\frac{1}{2}$	.3125	.0830	60	15	1.250	2.655
16	$2\frac{5}{8}$	.3333	.0975	61	$15\frac{1}{4}$	1.292	2.883
17	$2\frac{3}{4}$	.3542	.1135	62	$15\frac{1}{2}$	1.333	3.118
18	$2\frac{7}{8}$	.3750	.1309	63	$15\frac{3}{4}$	1.375	3.369
19	$3$	.3958	.1498	64	16	1.417	3.632
20	$3\frac{1}{8}$	.4167	.1704	65	$16\frac{1}{4}$	1.458	3.901
21	$3\frac{1}{4}$	.4375	.1924	66	16	1.500	4.188
22	$3\frac{3}{8}$	.4583	.2161	67	$16\frac{1}{2}$	1.542	4.488
23	$3\frac{1}{2}$	.4792	.2416	68	17	1.583	4.792
24	$3\frac{5}{8}$	.5000	.2687	69	$17\frac{1}{4}$	1.625	5.115
25	$3\frac{3}{4}$	.5208	.2974	70	$17\frac{1}{2}$	1.667	5.453
26	$3\frac{7}{8}$	.5417	.3283	71	$17\frac{3}{4}$	1.708	5.795
27	$4$	.5625	.3606	72	18	1.750	6.156
28	$4\frac{1}{8}$	.5833	.3950	73	$18\frac{1}{4}$	1.792	6.533
29	$4\frac{1}{4}$	.6042	.4313	74	$18\frac{1}{2}$	1.833	6.913
30	$4\frac{3}{8}$	.6250	.4693	75	$18\frac{3}{4}$	1.875	7.316
31	$4\frac{1}{2}$	.6458	.5094	76	19	1.917	7.732
32	$4\frac{5}{8}$	.6667	.5515	77	$19\frac{1}{4}$	1.958	8.153
33	$4\frac{3}{4}$	.6875	.5956	78	$19\frac{1}{2}$	2.000	8.597
34	$4\frac{7}{8}$	.7083	.6416	79	20	2.083	9.516
35	$5$	.7292	.6901	80	$20\frac{1}{4}$	2.167	10.506
36	$5\frac{1}{8}$	.7500	.7402	81	$20\frac{1}{2}$	2.250	11.541
37	$5\frac{1}{4}$	.7708	.7928	82	$20\frac{3}{4}$	2.333	12.635
38	$5\frac{3}{8}$	.7917	.8475	83	21	2.417	13.802
39	$5\frac{1}{2}$	.8125	.9044	84	$21\frac{1}{4}$	2.500	15.018
40	$5\frac{5}{8}$	.8333	.9633	85	$21\frac{1}{2}$	2.583	16.296
41	$5\frac{3}{4}$	.8542	1.0249	86	$21\frac{3}{4}$	2.667	17.653
42	$5\frac{7}{8}$	.8750	1.0884	87	22	2.750	19.059
43	$6$	.8958	1.1542	88	$22\frac{1}{4}$	2.833	20.530
44	$6\frac{1}{8}$	.9167	1.2228	89	$22\frac{1}{2}$	2.917	22.084
45	$6\frac{1}{4}$	.9375	1.2933	90	$22\frac{3}{4}$	3.000	23.689

## MEASUREMENTS BY A VEE NOTCH OF ANY ANGLE

Referring again to the general formula,  $Q = 4.28mT\sqrt{h}^5$ , we see that, so long as the coefficient  $m$  remains constant, the discharge will be proportioned to the factor  $T$ ; that is, proportioned to the tangent of  $\frac{1}{2}$  the angle of the notch, and the following general proposition may be affirmed:

The discharge of a quadrantal weir ( $90^\circ$ ) as given in Table XXXIII, is to the discharge of one having a different angle, as 1 (tangent  $45^\circ$ ), is to the tangent of one-half the other angle.

Selecting a case that is proved by the work already done:

*Example.* What will be the discharge through a vee notch embracing an angle of  $60^\circ$ , under a head of  $9\frac{1}{2}$  ins.?

Disregarding for the moment the table and formulas applicable to this angle, we find that a quadrantal weir under this head would discharge 1.4680 second-feet. The tang. of  $45^\circ$  ( $\frac{1}{2}$  of  $90^\circ$ ) is 1, the tang. of  $30^\circ$  ( $\frac{1}{2}$  of  $60^\circ$ ) is 0.57735, from which by the proposition above stated we have the following proportion:

1 : 0.57735 :: 1.4680 : Answer, = 0.8475 second-feet. This result agrees with the table prepared for weirs of that angle.

It is probable that as the weir angle becomes very large or very small the value of  $m$  would require some modification, but for all angles suitable for gauging purposes, the proposition as above stated will hold true.

## LIMITING VELOCITIES

Generally speaking, in hydraulic work there is economy in using the highest practical velocity, for a smaller and less expensive conduit may be employed to convey any specified volume of water. The velocities it is possible to employ are, however, limited in many ways, and are often confined between rather narrow bounds by the strength and endurance of structural material on one hand, and the necessary economy of funds upon another. Very high velocities are sometimes used to great advantage where the pressure is unusually heavy, as the size and cost of iron pipe are thus very greatly reduced; but as the velocities rise, the friction losses increase rapidly, and the mechanical wear, if the water carries even a small amount

of sediment, becomes a source of constant annoyance and expense.

The foregoing suggests the highest practical velocity for economic reasons; but it is quite as important, and very often far more difficult, to so adjust the limits in an open channel as to prevent an aquatic growth or an accumulation of sediment on one hand, and to avoid an undue erosion or cutting of the banks upon the other. The satisfaction and economies that attend the use of a self-sustaining water-way, as compared with one that is forever filling up, are so great that the subject should always receive careful attention.

#### IN IRON PIPES

	Mean Velocity Ft. per Sec.
(1) Maximum velocities to economize material under heavy pressure, may run as high as . . .	18 or 20
(2) Maximum in general work should not exceed..	10 or 15
(3) Maximum when head has an economic value, range from . . . . .	5 to 8
(4) Minimum, unless head is of great value, general range from . . . . .	3 to 4

#### IN OPEN FLUMES

(1) Maximum on straight lines when head has little value . .	10 to 15
(2) Maximum on curved lines (graduated to degree of curve) . . . . .	5 to 8
(3) On ordinary line, for lively work and little trouble . . . . .	5 to 6
(4) Minimum in economy of material should rarely go below . . . . .	4
(5) Minimum in economy of head should rarely go below . . . . .	2

#### IN OPEN CANALS AND DITCHES

To prevent erosion the maximum should not exceed:

(1) Maximum in fine sand and light soils . . . . .	2 to 2½
(2) Maximum in ordinary sand and loam . . . . .	2½ to 3
(3) Maximum in heavy sand, fine gravel and firm soils . . . . .	3 to 4
(4) Maximum in heavy gravel, small rock and tenacious soil . . . . .	4 to 5
(5) Maximum when rip-rapped, or lined with concrete, etc. . . . .	5 to 8
(5) Maximum in hard rock (regarding head as valueless) . . . . .	8 to 12

To scour a channel the minimum must not fall below:

	Mean Velocity Ft. per Sec.
(1) Minimum for fine silt and slimes.....	1½ to 2
(2) Minimum for fine sand and like material....	2 to 2½
(3) Minimum for heavy fine, or light coarse sand.	2½ to 3
(4) Minimum for heavy sand, or fine gravel.....	3 to 4

#### SEWER LINES AND CLOSED CONDUITS.

To secure a self-cleansing action therein:

- |  |   |
|--|---|
| (1) Minimum in all lines whose wet or working cross-section has an area of less than one square foot, about..... | 4 |
| (2) Minimum in all lines whose wet or working cross-section has an area of more than one square foot, about..... | 3 |

#### CONDUITS FOR WATER BURDENED WITH DETRITUS

To prevent undue friction and erosion:

- |   |        |
|---|--------|
| (1) Maximum, the wear becomes appreciable (depending somewhat on the hardness of the channel and character of the sediment) if the velocity ranges in excess of from..... | 4 to 5 |
|---|--------|

To prevent an aquatic growth,

- |  |        |
|--|--------|
| (2) Minimum (depending largely on the climate, temperature of the water, and character of bottom) ranges from..... | 2 to 3 |
|--|--------|

There are exceptions to every rule, and many might be noted here. Conduits that are very large or small, very rough or smooth, or those that are otherwise abnormal, are always *exceptions*, and should be so regarded. Not alone the specific gravity, but the size of a particle, goes far to determine its action when submerged—a fact that makes the meaning of such terms as fine and coarse, light and heavy, somewhat ambiguous; but in a general way the foregoing will express the relation that velocity bears to the materials encountered, and the conditions involved in the transport and control of large volumes of water.

**PART VII**

**DISCUSSION OF THE FORMULAS**



## PART VII

### DISCUSSION OF THE FORMULAS

#### PRELIMINARY REMARKS

IN the early dawn of progress, man must have observed with some attention the ever-present phenomena of running water; and from that day to the present, a large part of his life must have been spent in close touch, if not in actual conflict, with the natural forces that are manifest in every shower that revives the earth, and in every stream on its way to the sea. Under the circumstances it is perhaps quite natural to expect that the forces involved in a movement so familiar would be perfectly understood, and that in our formulas for the flow of water we would long ere this have settled upon standards that would be very generally accepted.

It is usually a surprise when the student learns that this has not been done, and he is quite too willing to regard his predecessors as unprogressive and far behind the times. Engineers that specialize in other lines, with but a superficial knowledge of this subject, readily conclude that all hydraulic formulas are more or less untrustworthy and unnecessarily involved, oblivious of the fact that their difficulties are largely personal, and are apt to assume that some *simpler* expression might be devised that would be more *generally* applicable, without realizing that these two requirements are directly antipodal.

There is no department of engineering activity, perhaps, in which personal judgment, born of close observation and long experience, counts for more than in the hydraulic field, and the call for a formula that can be used to advantage by the novice in hydraulic work without further investigation or experience is not likely to be answered in the immediate future.

There is a vast fund of misinformation upon this subject that passes current with many able men both in and out of the profession. It is a mistake to assume that there is now a large

amount of unassimilated material available for revising our formulas, that data sufficiently exact for this purpose are accumulating rapidly, or that their collection is not a slow and usually profitless undertaking. As a matter of fact, by far the larger part of these so-called data, including much that was at one time highly regarded, would now be rejected as not being precise enough for modern requirements.

To the layman it appears a simple matter to obtain the grade or slope of a large stream, but the experienced engineer understands that it requires much special equipment, and repeated measurements by a trained observer, to determine with any degree of correctness either the mean velocity or the actual slope in the channel of an ordinary river. Neither can the diameter of an artificial conduit be accurately determined without a more careful calibration than is generally used in the factory; while its practical working cross-section is likely to be affected by the degree of mechanical perfection in finishing and joining.

All hydraulic formulas are more or less empirical in character, and cannot express a greater measure of refinement than was manifest in the experiments from which they were evolved. To possess any practical value for further development it is necessary that the experiments be more exact, or that they cover other ground, than those used in evolving the original expression.

That our hydraulic expressions for velocity differ greatly in form and action cannot be denied; but there is no warrant for the assumption that all are more or less untrustworthy, or that little reliance can be placed upon the results we may obtain. On the contrary, a fuller investigation will show that nearly all the modern expressions now in general use are entirely trustworthy when confined to the field from which they have been evolved, and that in the hands of those who understand their application will give results that for every practical purpose are in fair accord.

With the foregoing remarks as a prelude, offered by way of explanation rather than apology, we will proceed to consider a few of the great number of equations that have been developed relating to the flow of water.

Gravity, the value of which has been accurately determined, is the usual force that actuates the flow of water; but the influences that may tend to retard it are both numerous and

elusive and their action complex and involved to a degree that often defies a perfect analysis.

Symbols, as generally used in modern hydraulics, will be used in this work to represent quantities and qualities, as follows:

#### VALUE OF SYMBOLS AS USED IN THIS DISCUSSION

$v$  = mean velocity in feet per second.

$a$  = area of wetted cross-section in square feet.

$p$  = wetted perimeter in lineal feet.

$r$  = hydraulic mean depth =  $\frac{a}{p}$ .

$h$  = head, or fall per unit length.

$l$  = length, or distance traversed for a unit fall.

$s$  = sine of the angle of inclination; a unit fall divided by the distance, also expressed as equaling  $\frac{h}{l}$ .

$f$  = fall in feet, in the old English mile of 5000 ft. (used only in Brandreth's modification of Bazin's formulas).

$g$  = acceleration of gravity = 32.16 ft. per second (used as 32.2).

$c$  = coefficient of discharge, or of mean velocities of flow.

$Q$  = discharge in cubic feet per second.

$n$  = a coefficient of rugosity or roughness (used only in connection with Kutter's formula).

#### OLD HYDRAULIC FORMULAS

Very little exact information regarding the flow of water was available for the early writers upon this subject. We are told that many unwarranted and misleading hydraulic assumptions passed current in the literature of the day, and many fallacies that now appear ridiculous were repeated and handed down without comment or correction.

About the year 1730, Henri Pitot, by using a bent tube which through many modifications has since borne his name, made a series of current measurements that did much to separate the worthy from the worthless theories of the older writers. Some twenty years later Brahms suggested as a function of velocity, the ratio between the wet area and the wetted perimeter; and

later in conjunction with M. Chézy, an eminent French engineer, offered the following as an equation for velocity:  $v = c \sqrt{\frac{a}{p}} \times \frac{h}{l}$ .

This expression, slightly modified and usually written  $v = c \sqrt{rs}$ , is now very generally known as the Chézy formula. It is predicated upon the theory that the hydraulic radius, and the sine of the angle of inclination, are both functions of the velocity; an assumption that appears to have been generally recognized as founded upon correct hydraulic principles, since it has retained its present form for more than a century. Nearly all formulas for velocity, both ancient and modern, are identical in that the value of  $v$  will vary as the square root of the factors  $r$  and  $s$ , that are usually instrumentally determined, and in which  $c$  will appear as a coefficient whose value must be determined by experiment.

Though far from complete, the following list gives the value of  $c$ , as found, or rather as used, by a number of early authorities:

Chézy	100	Blackwell	95.8	D'Aubisson	100 and 68
Downing	100	Hawksley	96.1	Beardmore	100 and 94.2
Leslie	100	Bartlett	95.9	Neville	93.3 and 92.3
Taylor	100	Young	84.3	Stevenson	96.0 and 69.0
Pole	100	Kirkwood	80.0	Eytelwein	100.0 and 93.4

One hundred is repeatedly named in the above list as the value of  $c$ , partly, we may suppose, because it is a very convenient factor; but mainly, no doubt, because that figure is close to its mean value for small well-finished conduits, for large canals less carefully constructed, and for a wide range of streams in their natural bed.

Let those who desire a *simple* expression for velocity adopt the Chézy formula ( $v = c \sqrt{rs}$ ); which, when  $c$  has a value of 100, may be expressed in a rule that is easily remembered, to wit:

**RULE.** Multiply the square root of the hydraulic radius in feet by the square root of the sine of the angle of inclination; move the decimal two points to the right, and read the mean velocity in feet per second.

That a very large proportion of the questions that arise in ordinary work can be closely approximated by this simple equation may be a surprise to many.

Though the coefficient of flow was often used as a constant, that it was generally recognized as a variable is shown by the

number of authorities that have suggested two or more values other than 100 for use in the same formulas, in an effort to adjust their expressions to some noted change in the character of the channel, or to some observed condition of the flow. When we note that the Kutter formula (when  $n = .013$ ) gives values for  $c$  varying from 65.6 for a pipe 5 ins. in diameter to 146.0 for a conduit that is 20 ft. in diameter, and reflect that for open channels the practical range for the coefficient of flow is far greater than this, we can readily appreciate why the double values as suggested by Beardmore, D'Aubisson, Stevenson and others, fail as the field in which they are used expands beyond the range of their experimental work.

Again, with all the authorities named, when any change in  $c$  is proposed, aside from being too feeble to render the formula generally applicable, it is sudden and abrupt from one value to another, and in this respect fails to harmonize with the fundamental conditions of the flow as we now understand them.

### MODERN FORMULAS

We can hardly hope to express a complex proposition clearly with a simple formula, and for that reason all critical and trustworthy equations relating to the flow of water are of necessity somewhat involved. Nearly all the more complex modern expressions for velocity can, in some way, be reduced to terms of the Chézy formula, when it will appear that the factors  $v$ ,  $\sqrt{r}$  and  $\sqrt{s}$ , all bear a consistent relation one to another, and that the coefficient  $c$  is really the involved factor through which the value of  $v$  is independently modified. To make this entirely clear, note that the complex terms within the brackets in D'Arcy's formulas (18) and (19), the term within the large brackets in Kutter's formula (30), and the terms under the radical in Bazin's formulas (20), (21), (22) and (23), are the only features in which any of these expressions differ, in short, the involved term in each but expresses the value of  $c$ , a coefficient of the flow.

Though noted elsewhere, it is relevant here to repeat, that with proper equipment the value of  $r$ , which is a measure of capacity, and the value of  $s$ , which is a measure of the slope, can always be determined within comparatively narrow limits. Upon the other hand the coefficient  $c$  is empirical in character,

and its value as used in the respective formulas is presumed at least to have been determined entirely by experiment.

In a general way  $c$  expresses the sum of all the retarding influences. It is the vulnerable factor in all equations for velocity, and through it are introduced all serious discrepancies that appear. All other factors are relatively infallible, but  $c$  is always reflecting our imperfect judgment regarding the retarding effects of roughness, erratic current velocities, and a changing cross-section.

The formulas of Gauchler, Molesworth, D'Arcy, Bazin, and Kutter have each been developed by engineers of marked ability and wide experience. Each of these, with others that are not named, are possessed of some special merit in some particular field; and most of them are used with confidence by those who have made themselves familiar with their application. All the authorities just named have in some manner recognized the influence of rugosity and the effect of the hydraulic radius upon the flow; while Gauchler, Molesworth, and Kutter have made their coefficients of the flow to depend, in some degree, upon the grade or current velocity. All are not equally applicable, however, and with the possible exception of Kutter, the field over which any of them can be confidently employed is comparatively small.

My preference for the formulas of D'Arcy, Bazin, and Kutter is due in part, no doubt, to my having used them in my practice since the appearance of Flynn's work; but a further incentive for their selection for computing the tables previously given will be found in the practical and comprehensive series of tabulated factors that his work contains.

His "Flow of Water in Irrigation Canals" has, I understand, been out of print for a number of years, and it is no longer an easy matter to obtain a copy. The saving, however, in both time and energy that may be effected by using his factors in all computations that involve either the D'Arcy, the Bazin, or the Kutter formulas is so great that I hope the profession may again find his work available at a price that a young engineer can afford to pay.

I am under numerous obligations to many hydraulic authorities, but I feel doubly indebted to Mr. Flynn; not alone for his tables, that have greatly facilitated my work, but for a rich fund of hydraulic information, and for his very complete collection

of velocity equations, together with many interesting and suggestive modifications thereof, from which I have gleaned generously for the formulas and comparisons that follow.

### THE D'ARCY FORMULAS FOR IRON PIPES RUNNING FULL

The D'Arcy formulas were developed from carefully conducted experiments by an eminent authority, under conditions that inspire unusual confidence in their application to all problems that come with the range of his work. D'Arcy's experiments were, however, conducted upon pipes that were generally between 3 and 20 ins. in diameter. It has always been a matter of general regret that his work did not include conduits of larger capacity and a wider range of roughness. Other workers have since confirmed his coefficients for pipes of larger diameters, and many engineers prefer to use his formulas, and regard them as trustworthy, for pipes that are 5 ft. or more in diameter.

The D'Arcy formulas for velocity, as presented by J. B. Francis for measurements in feet, and given on pages 221 and 222 of Flynn's work, are as follows:

For clean cast-iron circular pipes when running full,

$$v = \left( \frac{144d^2s}{.00371(12d+1)} \right)^{1/2} \dots \dots \dots (16)$$

For old cast-iron circular pipes when running full,

$$v = \left( \frac{144d^2s}{.0082(12d+1)} \right)^{1/2} \dots \dots \dots (17)$$

At the reference just given will also be found Flynn's method of reducing the foregoing to the forms that follow:

For clean cast-iron circular pipes when running full,

$$v = \left( \frac{155256d}{12d+1} \right)^{1/2} \times \sqrt{rs} \dots \dots \dots (18)$$

For old cast-iron circular pipes when running full,

$$v = \left( \frac{70243.9d}{12d+1} \right)^{1/2} \times \sqrt{rs} \dots \dots \dots (19)$$

These equations were used by Mr. Flynn in compiling the tables from which I have taken the values of  $c\sqrt{r}$ , for computing the two D'Arcy flowage Tables I and II.

D'Arcy anticipates but two degrees of roughness and presents a distinctive formula for each degree. It follows that the field within which either can be reliably employed is quite limited, while the abrupt change from one formula to another does violence to our ideas regarding the influence of roughness in a gradually deteriorating pipe line.

On referring to formulas (18) and (19), it will appear that the coefficient  $c$  (the term within the brackets), will not change except as the value of  $d$  is changed, that is, D'Arcy's coefficients are made to depend entirely upon the diameter. It will further appear that the factor  $+1$ , in the denominator, will have but little effect upon the result unless the diameter be small, something less than 1 ft. we may say. In other words, the D'Arcy velocity curves do not curve appreciably unless the value of  $d$  be very small; that for diameters of 4 or 5 ft. the curvature is very slight, while for diameters greater than 10 ft. the influence of the factor  $+1$  becomes negligible and the curve becomes for every practical purpose a straight line. This action of the D'Arcy formulas will be confirmed by comparing his values of  $c$  for the several values of  $r$  as shown in Table XXXV, while a close inspection will detect this feature manifested graphically in the Charts I, II, III and IV, as they appear in the Appendix.

Nor are the D'Arcy coefficients affected in any way by the velocity of the current or the slope of the channel, that is, his values of  $c$  are the same for all values of  $s$ . For this reason his formulas are not generally regarded as applicable to pipes of large diameters or to conduits of great capacity.

In the realm of small pipes, however, or for medium-sized closed conduits with but a moderate degree of roughness, D'Arcy's coefficients have unquestioned experimental confirmation, and in this particular field most hydraulic engineers regard his formulas as more reliable than any other.

## THE BAZIN FORMULAS FOR SMALL OPEN CHANNELS

D'Arcy and Bazin were associated to some extent in their experimental work; but the name of the latter is more intimately connected with the four following equations for velocities in small open channels, and which are generally known as the Bazin formulas:

For even and fine plastered surfaces, planed planks, etc.,

$$v = \sqrt{1 \div .0000045 \left(10.16 + \frac{1}{r}\right)} \times \sqrt{rs}. \quad (20)$$

For even surfaces, brickwork, cut stone, unplanned plank, etc.,

$$v = \sqrt{1 \div .0000133 \left(4.354 + \frac{1}{r}\right)} \times \sqrt{rs}. \quad (21)$$

For slightly uneven surfaces, rubble masonry, etc.,

$$v = \sqrt{1 \div .00006 \left(1.219 + \frac{1}{r}\right)} \times \sqrt{rs}. \quad (22)$$

For uneven surfaces, channels in earth, etc.,

$$v = \sqrt{1 \div .00035 \left(0.2438 + \frac{1}{r}\right)} \times \sqrt{rs}. \quad (23)$$

Of the foregoing, Mr. Flynn remarks that with small open channels in earth of less than 20 ft. bed width and in good order, Bazin's formula No. 23 has given very fair results; and that tables based upon it have been used by the Irrigation Department of Northern India for velocity computations in distributing channels with success. This particular formula, as applied to channels of moderate width (bed widths of 20 ft. or less) appears to have received an unusual amount of experimental confirmation, and Mr. Flynn gives a velocity and discharge table which was computed for the Panjab Irrigation Department by Captain Allen Cunningham, R.E., by a modification of Bazin's formula (23) given by Captain A. B. Brandreth, R.E., for channels in earth.

I have followed Captain Brandreth's method as given on page 16,\* of Flynn's work, in reducing the first, second, and third forms of the Bazin formulas to the forms that follow:

For even, and fine plastered surfaces, planed planks, etc.,

$$v = \frac{2r}{\sqrt{.09 + .9144r}} \times \sqrt{f}. \quad (24)$$

\* Should this reference be used the reader should be on guard, as three serious typographical errors appear on this page, though the general result is correctly stated in the first equation near the top.

For even surfaces, brickwork, cut stone, unplanned planks, etc.,

$$v = \frac{2r}{\sqrt{.266 + 1.1582r}} \times \sqrt{f}. \quad . \quad . \quad . \quad (25)$$

For slightly uneven surfaces, rubble masonry, etc.,

$$v = \frac{2r}{\sqrt{1.2 + 1.4628r}} \times \sqrt{f}. \quad . \quad . \quad . \quad (26)$$

For uneven surfaces, channels in earth, etc.,

$$v = \frac{2r}{\sqrt{7.0 + 1.7066r}} \times \sqrt{f}. \quad . \quad . \quad . \quad (27)$$

These formulas have been used for computing Tables XIII, XIV, XV, and XVI, respectively.

These modifications do not change the action of the formula in any respect, nor do they in any manner affect the results obtained. My computations for the tables have, for the most part, been confined to the channel dimensions confirmed by the Panjab experiments on formula (23), but for the sake of securing a comparison with Kutter over a wider field, I have, for the tables and charts in the Appendix, extended them far beyond the limits covered by Bazin's experiments, and beyond the range within which the formulas are supposed to be applicable.

The Bazin formulas anticipate but four degrees of roughness, which restricts their application to a limited range of surface conditions, and, as with D'Arcy, the degrees change suddenly from one value to another, and thus fail to harmonize with the theory that resistance gradually increases as the inclosing walls become rougher.

Turning now to the formulas (20) to (23) inclusive, it will clearly appear that the coefficient  $c$  (the term under the radical), will not change except as the value of  $r$  is changed, that is, the Bazin coefficients are made to depend entirely upon the hydraulic radius. It will be seen further that his coefficients will not be affected by any change in the current velocity nor by any change in the slope of the channel, a feature that in the estimation of nearly all hydraulic engineers would prevent his formulas, like those of D'Arcy, from being generally applied to channels of large capacity or lines having any considerable grade.

With the Bazin formulas it is far more difficult than with those of D'Arcy to follow the effects upon  $c$  of any change made in the value of  $r$ , nor is it easy to trace these effects in the value of the coefficients as given in Tables XXXVI and XXXVIII. These effects are, however, fairly reflected in the velocity curves shown in Chart XXI, where the action of the respective formulas may be readily traced. It is not altogether fair, perhaps, to discuss the working of an equation far beyond its reputed radius of action, as I am doing, but it is of interest to note that formulas (20) and (21) each develop a slight and even curve with the concave side toward the ordinate axis, that the curve of (23) at no point departs very far from a straight line, but is somewhat erratic in that it is twice reversed, while equation (24) develops a line that departs further from a straight line and presents greater curvature than either of the others, with its convex side to the axis of ordinates.

It thus appears that of the four Bazin formulas, his fourth form (24), the one that comes most highly recommended and claims extensive experimental confirmation, develops the most erratic velocity curve.

A bed width of 20 ft. is named as a limit within which this expression has been successfully used. As Bazin's coefficients are made to depend upon the value of  $r$ , it would be more logical at least to define the limits in terms of the hydraulic radius. No special depth is mentioned, but I translate the expression as meaning that, in the experimental work referred to, the value of  $r$  did not exceed about 2 ft., or the value of  $\sqrt{r}$  about 1.4 ft.

The velocity curves, as they appear in the chart, seem to indicate that this limit is quite high enough for his fourth form (24), but I can see nothing therein to prevent the application of his third form (23), to channels whose hydraulic radius is greater than 2 ft.; in fact Bazin's formula (23), and Kutter's formula, when  $n = .017$  and  $s = .0003$  (the values used in computations for chart 21), might be used indiscriminately, but it must be remembered that Kutter will develop a different value for  $c$  for every change in the value of  $s$ , while the Bazin coefficients will remain unaltered.

Bazin's first and second forms, (20) and (21), ostensibly designed for open channels, seem to contemplate a degree of roughness (or, rather, smoothness), that is seldom found in

conduits of this character. The range through which they, or either of them, can be used for open channels in earth is really very narrow.

In spite of all strictures herein noted, and in spite of the limitations placed about the Bazin formulas, his equations of the third and fourth forms, (22) and (23), may be regarded as fairly trustworthy when applied to open channels in earth of moderate dimensions, with but the ordinary range in roughness, and with such slopes as are generally employed in such work—limitations, by the way, that do not exclude by far the larger part of all hydraulic work that comes to the mining, the agricultural, or the irrigation engineer.

### KUTTER'S FORMULA

While the formulas that have been offered by D'Arcy, Bazin, Fanning, Humphrey and Abbot, Kutter, and other eminent authorities, are all fairly trustworthy when used within the field from which they have been evolved, and while nearly all possess some feature of special merit, the only one appearing as at once generally applicable, as sufficiently reliable, and yet not too involved for ordinary professional service, is the expression developed by Ganguillet and Kutter, and now familiarly known as Kutter's formula.

Kutter's formula for  $c$ , a coefficient of flow, when adapted for metric measurements, is as follows:

$$c = \frac{\frac{1}{n} + 23 + \frac{.00155}{s}}{1 + \left(23 + \frac{.00155}{s}\right) \times \frac{n}{\sqrt{r}}} \quad \dots \quad (28)$$

Kutter's formula for  $c$ , a coefficient of flow, when adapted for measurements in feet, is as follows:

$$c = \frac{\frac{1.811}{n} + 41.6 + \frac{.00281}{s}}{1 + \left(41.6 + \frac{.00281}{s}\right) \times \frac{n}{\sqrt{r}}} \quad \dots \quad (29)$$

Kutter's formula for velocity, when adapted to measurements in feet, is as follows:

$$v = \left( \frac{\frac{1.811}{n} + 41.6 + \frac{.00281}{s}}{1 + \left( 41.6 + \frac{.00281}{s} \right) \times \frac{n}{\sqrt{r}}} \right) \times \sqrt{rs} \quad (30)$$

The labor involved in developing this expression cannot be appreciated without following the authors closely in their original work, a step that is now rendered possible for English students through a translation made by Rudolph Hering and John C. Trautwine, Jr., published in 1889 by John Wiley & Sons, New York.

This labor involved much careful research through a vast amount of original data, the critical analysis of considerable doubtful and disconnected experimental work, and the rejection of such material as was not considered sufficiently exact or entirely reliable; all this, in simply preparing for the task they had undertaken.

Their methods are too involved to be abridged with any degree of satisfaction, nor can their discussion be readily followed without some knowledge of advanced mathematics; but as one reviews their work, he is impressed by their evident qualifications for the task, and by the logical character of their deductions, while his convictions are strengthened regarding the practical value of the formula developed.

The efficiency and sensitive flexibility of Kutter's formula in responding to changing conditions, that make its application over so large a field possible, are largely secured by a full appreciation of the influence that surface roughness exerts upon the flow, and by the introduction of a special and variable factor  $n$ , whose graduated value should express the degree of surface rugosity presented by the walls of the conduit or channel.

The problem of developing such a factor was first attacked by dividing the great variety of channels upon which reliable data could be obtained into twelve classes, arranged with reference to their surface roughness, and later determining by calculation and comparison numerical values for the influence of roughness, which when substituted in the formula would represent its effect for the channels that belonged to each particular class. These numerical coefficients, or values of  $n$ , were then set forth in tabular form (see table on pages 12 and 13), with such a description appended to each as would serve to

define the channel characteristics from which it had been derived.

This special factor for roughness, as used in the Kutter formula, is wholly empirical in character, and its value cannot be instrumentally determined. Its selection is exclusively a matter of judgment, after an inspection of the character and condition of the water-way, and a proper estimate of its value is often a troublesome task.

The influence of  $n$  upon the value of  $c$  in the formula is usually quite pronounced and is always inverse; that is, as the value of  $n$  is increased, that of  $c$  is decreased, and the velocity is diminished.

The factor  $r$ , which symbolizes the hydraulic radius, is usually a measure of the capacity of a conduit, and its effect upon  $c$  is always direct; that is, as  $r$  is increased, the coefficient of the flow  $c$  and the mean velocity are increased, and as  $r$  is decreased they are both diminished. It is the square root of this factor that is used in the formula, wherein it makes a double appearance, first in determining the value of  $c$  and again for obtaining the mean velocity. The square root of  $r$ , more often probably than any other factor, appears to dominate in the results obtained by the formula.

The factor  $s$  makes a triple appearance in the Kutter formula, twice in obtaining the value of  $c$ , in which its influence is comparatively slight, and again when its square root performs an important function in determining the mean velocity. Its influence upon  $c$ , though regarded as important, is somewhat paradoxical, from the fact that its effect is greatest when its own value is least. Its influence on  $c$  diminishes as it is increased until it becomes negligible on all slopes greater than 1 in 1000 or when  $s$  has a value as great or greater than .001; indeed the influence of  $s$  upon  $c$  is trifling on all slopes greater than 1 in 2000, or when  $s$  is greater than .0005. A further peculiarity in the action of  $s$  appears in that, for all values of  $r$  less than 3.281 ft.\* its diminution diminishes the value of  $c$ ; while for all values of  $r$  greater than 3.281 ft. a diminution of  $s$  increases the value of  $c$ .

Without large experience with the formula, it will be no easy matter for the reader to follow the relations of the Kutter fac-

\* The numeral 1.811 in our formula is the square root of 3.281 ft., or 1 meter as used in Kutter's original expression.

tors through the cold and cloudy statement of facts as above given, but if further interest attaches to this branch of the subject, the student is referred to an article in the Appendix and to Tables XXXV, XXXVI, XXXVII, and XXXVIII, in which values of  $c$ ,  $n$ ,  $s$  and  $v$  have been systematically arranged for comparison.

The Kutter formula is no doubt far from perfect, but it has received an unprecedented amount of experimental confirmation, over a wider range than has ever before been attempted, with results that are regarded by the best authorities as fairly satisfactory. As Kutter's data were generally drawn from experiments upon large conduits and open channels, cautious engineers have questioned the reliability of his formula when applied to closed pipes of small diameter. In this particular field many engineers are inclined to follow D'Arcy (see article in the Appendix above referred to), but in every other department Kutter seems to be preferred by a large majority.

I have not hesitated in expressing a preference for Kutter, but if in the foregoing pages I have at times appeared to assume that results that did not agree with him were necessarily in error, I wish to remark that my technical equipment nor my practical experience have neither been of a character that would entitle me to an independent opinion upon many matters of which I have written. My opinions have no academic significance and my comparisons are in all cases just what my computations have made them appear.

I do not regard Kutter's curves as a *standard* except as a basis for comparison, nor do I contend that his results are always more exact than others'; yet, after the foregoing study of his factors in action, after noting the sensitive manner in which his formula responds to every change in channel conditions, and after observing the regular and consistent traverse of his velocity curves over the entire range as they appear in Chart XXI, I think we have many reasons for regarding with suspicion any equation that does not produce a curve that is closely parallel, at any rate, with those developed by Kutter.

Mr. Flynn, in his "Flow of Water in Irrigation Canals, etc." (pages 213 to 216 inclusive), proposes a modification that greatly simplifies all operations by Kutter's formula and deserves more than passing attention. It may be confidently used in the field it is intended to cover, which will embrace all medium-sized

conduits, on the slopes most frequently employed—a very large per cent indeed of all the channels, pipes, and conduits that are in ordinary use. At the risk of working an author beyond professional limits, I will close my discussion of Kutter by presenting Flynn's modification, which is quite too practical and efficient to remain buried in a work that has for years been almost unobtainable.

### FLYNN'S MODIFICATION OF KUTTER'S FORMULA

Regarding this, Flynn observes in substance: since the influence of  $s$  on the value of  $c$  may be neglected on all slopes greater than 1 in 1000, and since for flatter slopes even up to 1 in 2640, its effect is too small to change the result materially; it is possible to make a modification of Kutter's formula that will give results near enough for all practical purposes, on pipe lines of the size and character generally employed in municipal work, and for such slopes as are ordinarily given. (See page 213.)

In illustrating the proposed modification, Flynn assumes an instance where the slope is 1 in 1000,  $s = .001$ , and  $n = .013$ ; and substitutes these values in Kutter's formula No. 29, when we have:

$$c = \frac{41.6 + \frac{1.811}{.013} + \frac{.00281}{.001}}{1 + \left( 41.6 + \frac{.00281}{.001} \right) \frac{.013}{\sqrt{r}}} \quad \dots \quad (31)$$

Reducing the above we obtain:

$$c = \frac{183.72}{1 + \left( 44.41 \times \frac{.013}{\sqrt{r}} \right)} \quad \dots \quad (32)$$

On inspecting equation (31), it becomes evident that the value of the numerator will be affected mainly by the value assigned to  $n$ , and very slightly, if at all, by such values as are usually given to  $s$ . It will further appear that the term within the brackets of the denominator will never differ greatly from 44.41; as it appears in equation (32) after its reduction. (Page 216.)

In proceeding, Mr. Flynn says: "If we call the numerator

on the right hand of the equation  $K$ , for any value of  $n$  we have":

$$c = \frac{K}{1 + \left(44.41 \times \frac{n}{\sqrt{r}}\right)}, \quad \dots \quad (33)$$

and,

$$v = \left( \frac{K}{1 + \left(44.41 \times \frac{n}{\sqrt{r}}\right)} \right) \times \sqrt{rs} \quad \dots \quad (34)$$

Here we have a modification of Kutter's formula for obtaining the numerical value of  $c$  that is simpler in form, and more easily applied than any velocity expression heretofore presented. Further, it is sufficiently accurate for most practical purposes, and may be applied with confidence to the character of circular pipes, or closed conduit, that are most frequently employed in municipal work. I have reworked and checked the following table of values of  $K$ , for substitution in equation (34), over practically the same range of  $n$  as given by Mr. Flynn.

TABLE OF VALUES FOR  $K$

$n$	$K$	$n$	$K$	$n$	$K$	$n$	$K$
.009	245.63	.013	183.72	.017	150.94	.021	130.65
.010	225.51	.014	177.77	.018	145.03	.022	127.73
.011	209.05	.015	165.14	.019	139.73	.023	123.15
.012	195.33	.016	157.60	.020	134.96	.024	119.87

*Example.* Assume that the diameter of a pipe is 2 ft. ( $\sqrt{r} = .707$ ), that  $n = .013$ , and  $s = .002$ , ( $\sqrt{s} = .044721$ ), then we have:

$$v = \left( \frac{183.72}{1 + \left(44.41 \times \frac{.013}{.707}\right)} \right) \times .707 \times .044721 = 3.1977 \text{ ft.} \quad (35)$$

Operation:

$$.013 \div .707 = .018387 \times 44.41 = .816567 + 1,$$

then,

$$183.72 \div 1.816567 = 101.1358 \times .707 = 71.503 \times .044721 = 3.1977 = v.$$

By the formula we obtain  $v = 3.1971$ . Even though the slope be reduced to 1.056 per mile, which is far below the limits named above, the value of  $c$  is reduced less than 5 per cent below that obtained by using the unmodified form of Kutter.



## **APPENDIX AND CHARTS**



## APPENDIX

My main object in constructing the charts that follow has been to secure a fair comparison of the formulas used in computing the flowage tables, when applied to a systematic gradation of channel capacities, with a broad variation in the angles of inclination and a wide range in the degrees of roughness employed. That this purpose might be more fully accomplished, many of the curves have been extended outside of the practical field and beyond the limits within which it was intended the formula should be used. Though it is often possible to obtain velocities direct from the charts, they are not at all comprehensive for this purpose and they should not be regarded as velocity plats; moreover, as all velocities in the field where any of the formulas are regarded as applicable can be obtained from the tables with a greater degree of accuracy, the necessity of using them for this purpose seems obviated.

The charts have all been constructed upon the same general plan; the values of  $\sqrt{r}$  have been plotted vertically and the respective velocities, under the conditions assumed, have been plotted horizontally. Charts I to XII compare the velocities obtained when the Kutter and D'Arcy formulas are applied to closed circular pipes when running full or under pressure. Charts XIII to XX compare the velocities obtained when the Kutter and Bazin formulas are applied to open channels, with varying slopes and different degrees of roughness.

In Chart XXI, the scale had been reduced to compare the velocities obtained by the D'Arcy, the Bazin, and the Kutter formulas over a wide range of values for  $r$ , regardless of whether the application be made to an open channel or a closed conduit. In Chart XXII the horizontal scale has been doubled, so that the velocity curves, which are somewhat confused in the upper part of Chart XXI, may be more readily traced. The comparison is interesting, though in making it I take an unwarranted liberty with both the D'Arcy and Bazin formulas by using them beyond the field they were designed to cover.

The grade or fall, the degree of roughness assumed, and the value of the  $\sqrt{r}$ , are all so distinctly marked upon each chart, together with all data essential for construction, that any further description or explanation thereof seems superfluous.

But a chart of the velocities obtained, though graphic and

quite practical for many purposes, does not exhibit the precise action of a formula with reference to the *coefficients of flow*. A comparison of the respective values which they give for the factor  $c$  is a more direct and logical method of proceeding, and it is with this fact in mind that tables numbered from XXXV to XXXVIII inclusive have been prepared.

Table XXXV compares the value of  $c$  as given by the Kutter and D'Arcy formulas, for fifteen graduated values of  $r$ , with special reference to the influence of rugosity upon the results. Note that D'Arcy anticipates but two degrees, while Kutter may be graduated to any desired value in either direction. Note further that D'Arcy's coefficients increase but slightly if at all beyond the limits of this table, while Kutter's will continue to increase, though with a diminishing ratio, as the size of the conduit is increased.

Table XXXVI compares the value of  $c$  as given by the Kutter formula (when  $s = .0003$  or a fall of 1.584 ft. per mile), with those obtained by the four formulas of Bazin, when applied to open channels. The coefficients of Bazin and D'Arcy are not affected by the slope and remain unchanged for all values of  $s$ .

Table XXXVII compares the value of  $c$  by D'Arcy's two formulas, and Table XXXVIII compares the value of  $c$  by Bazin's four formulas, with those obtained by using Kutter for equivalent values of  $r$  with special reference to the influence of  $s$  in modifying the value of Kutter's coefficients. The degrees of roughness assumed for comparison are purely arbitrary, but in a general way the values are in fair accord with the descriptions of rugosity as given by the authors. The sensitive flexibility of Kutter's formula in responding to every change in slope, as compared with the rigidity maintained in all the equations of D'Arcy and Bazin regarding the influence of  $s$ , becomes vividly apparent in the two tables last named.

It will be noticed that when  $\sqrt{r} = 1.8$  Kutter's coefficients are very nearly constant. (1.811 is the square root of 3.2809, which is one meter expressed in feet, a quantity that appears as unity in his original equation, thus making all values for  $c$  constant for this value of  $r$ ). Note also that when  $\sqrt{r}$  is less than 1.811 the value of  $c$  decreases as the slope is diminished, and that when  $\sqrt{r}$  is greater than 1.811 a decrease in the slope angle increases the value of  $c$ . This, I believe, is a feature peculiar to the Kutter formula.

The reversed functioning of  $s$  as above noted has never been accepted as entirely satisfactory by many hydraulic engineers, and indeed it seems to have been regarded by Kutter as rather a tentative expedient, advanced by him in an effort to adjust his formula to certain variations in velocity that his researches had compelled him to recognize. In this connection he candidly states that the experimental data available are not sufficient for a critical analysis, and it is almost the only point in an exhaustive discussion in which he appears to be questioning his own deductions.

Until quite recently the influence that eddy currents, or what has been aptly termed the *vortex movements*, may at times exert upon the flow has never been generally recognized, nor do I think that this feature is yet receiving the attention that its importance really demands. Fortunately, perhaps, in artificial channels the disturbance from this cause is relatively slight, and may usually be neglected with impunity. There are conduits, and there are stages of water in many streams, in which counter currents, or so-called vortex movements, become the dominant resisting force. The action is most conspicuous at a high stage of water in large streams with light gradients, in which more *head* is often dissipated in overcoming the adverse eddy currents than is consumed in the bed, bank, and air resistance all combined. That Kutter did not entirely overlook this influence is shown by the fact that he specifically mentions adverse currents, together with bends, an irregular cross-section, and roughness of the walls as conditions that combine to retard the flow.

The forces involved in a vortex movement are extremely illusive and their influence seemingly defies analysis. No systematic experiments have ever been conducted along this line so far as I am informed. It seems obvious, however, that, they are but indirectly related to the slope, that they are very largely independent of capacity, and that they are not dependent upon surface roughness in the sense in which we have been using that term. It is equally obvious that they will depend very largely upon surface *irregularities*, rather than surface roughness, and that they will be more closely related to velocity than to any other function in the formula. It seems quite impracticable to insert a function of velocity on the terminal side of a *velocity* formula, all of which leads to the conclusion

that their influence must, for the present, at any rate, be included in our estimate for roughness, or value that we assign to the factor  $n$ , for each individual case as presented.

A chapter might be devoted to the subject of eddy and counter currents, but space does not permit this, aside from the fact that a pocket hand-book should not be encumbered with matter of this character. This digression is intended to direct attention to a class of retarding influences that at times becomes very active without attracting general attention; a class of influences that, as the formula is constructed, can be recognized only by increasing the factor for roughness, as the vortex movements become more active, beyond the value which the same conditions would otherwise require.

It is quite impossible to express in a single equation the complex conditions of *flow* without introducing so many factors that the formula becomes too involved for general use. Kutter and Ganguillet seem to have reached the practical limit in this direction, if they have not, in fact, gone somewhat beyond it.

Kutter's formula is doubtless far from perfect in many respects, yet in one particular only, so far as I am able to discover, do carefully conducted experiments indicate that his expression is not as accurate and trustworthy as any here discussed, the exception being in the field of small conduits, when the hydraulic radius is less than 0.25 ft., when for reasons already given (see page 151), D'Arcy is generally preferred.

It is of interest to note that many engineers quite ingeniously *adapt* Kutter for use upon conduits of small capacity, by decreasing his coefficient  $n$  below that which his description of *surface* roughness would indicate should be employed. To illustrate, refer to Velocity Charts I, II, III, and IV, and note that at diameters of about 14 ins. the velocity curves of D'Arcy for clean cast-iron pipe is in accord with those of Kutter when  $n = .011$ , and that those of D'Arcy for old cast-iron pipe is in accord with Kutter when  $n = .015$ . Note further that at diameters of 7 ins., in order to accord with D'Arcy's curves, Kutter's  $n$  must equal 0.010 and .0135 respectively, and that at a diameter of 4 ins. his  $n$  must equal 0.009 and 0.012 respectively in order to accord with D'Arcy's experiments.

The method is arbitrary, and the illustration may overstate the requirements somewhat, as much depends on the slope and velocities under consideration, but the point I wish to

advance is this: that the flexible gradations of Kutter's factors may be retained, while the results are *forced* to accord with D'Arcy's experiments upon pipes of small diameter, by using a diminishing factor for roughness as the value of  $r$  is decreased.

It will be understood that many of the foregoing remarks are expressions of a personal opinion only, that they are offered without a pretense of experimental verification, that they are largely suggested by an intuition that accrues after years of rather attentive observation, and are advanced in the hope that some of them may assist, at times when the conditions are somewhat unusual, in selecting a workable value for Kutter's grievous factor for roughness.

There are good reasons for regarding some of the other formulas as less complex than Kutter's, and at one time it was doubtless true that computations could be more easily made by using them, but with the many tables that are now published to simplify such work, and particularly since the appearance of Flynn's tables of coefficients and factors, it appears to me that all velocity problems are more readily solved by Kutter's formula rather than by any other here mentioned.

The surprising discrepancies that so often appear, when different formulas are employed for the solution of the same problem, are naturally very disconcerting to the novice in hydraulics. The experienced engineer well understands that they are largely due to a difference in the degree of roughness assumed, but their persistent, frequent and unexpected recurrence—which the oldest in the profession often experience—does *not* tend to establish that unquestioned confidence in our hydraulic equations that old practitioners would like to enjoy.

Banishing for the moment all critical comments, at any time so easily made, we must in candor admit that a large majority of the more modern hydraulic equations are far more infallible than our personal judgment in estimating the variable factors that we are required to substitute therein in using them. Close analysis and a few candid comparisons will reveal the fact that they are exact to a degree well within the limits of our personal abilities. What more can we demand of an empirical formula? What more can one accomplish for us?

In conclusion, I may say that in my estimation Kutter's formula very fairly represents the sum of our present experimental knowledge in the field of hydraulics.

TABLE XXXV.—KUTTER AND D'ARCY FORMULAS

APPLIED TO CIRCULAR PIPES RUNNING FULL

Comparing the coefficients of flow, or values of  $c$ , with special reference to the influence of roughness upon the results.

Diam ft.ins.	$\sqrt{r}$ feet	Kutter, when $s = .001 = 5.28$ ft. per mile								D'Arcy	
		$n = .010$	$n = .011$	$n = .012$	$n = .013$	$n = .015$	$n = .017$	$n = .020$	$n = .025$	New Clean Iron Pipes.	Old Cast-iron Pipes.
1	.14	55.2	47.6	41.2	36.7	27.4	24.2	18.8	13.4	80.6	54.2
2	.20	71.0	61.6	54.1	48.0	38.7	32.1	25.2	18.1	92.9	62.5
3	.25	81.2	70.8	62.4	55.5	45.1	37.6	29.6	21.5	98.5	66.2
5	.33	95.3	83.5	74.0	66.2	54.2	45.4	36.2	26.4	103.2	69.4
7	.38	104.1	91.7	81.5	73.2	60.1	50.7	40.5	29.9	106.4	71.6
9	.43	111.1	98.0	87.3	78.7	64.9	54.9	44.1	32.7	107.9	72.6
1	.50	119.5	105.7	94.6	85.3	70.8	60.1	48.6	36.3	109.3	73.5
2	.71	138.5	123.6	111.3	101.1	85.0	73.0	59.8	45.5	111.5	74.9
3	.87	149.0	133.6	120.8	110.1	93.3	80.6	66.6	51.1	112.2	75.5
5	1.12	161.4	145.4	132.3	121.1	103.5	90.1	75.2	58.7	112.8	75.9
8	1.41	171.6	155.4	141.9	130.5	112.3	98.4	82.9	65.5	113.2	76.1
12	1.73	179.5	163.0	149.3	137.7	119.2	105.1	89.2	71.2	113.3	76.2
16	2.00	184.5	168.0	154.2	142.6	123.9	109.6	93.5	75.1	113.4	76.3
20	2.24	188.1	171.6	157.7	146.0	127.2	112.8	96.6	78.1	113.5	76.4
25	2.50	191.5	174.9	161.0	149.2	130.4	116.0	99.6	80.9	113.6	76.4

TABLE XXXVI.—KUTTER AND BAZIN FORMULAS

APPLIED TO FLUMES AND OPEN CHANNELS

Comparing the coefficients of flow, or value of  $c$ , with special reference to the influence of roughness upon the results.

$\sqrt{r}$ feet	Kutter, when $s = .0003$ or a fall of 1.584 ft. per mile						Bazin			
	When the values of $n =$						1st	2d	3d	4th
	.010	.012	.015	.017	.020	.025				
.39	101.1	79.0	58.4	49.3	39.4	29.1	115.7	83.5	46.7	20.7
.51	115.9	91.6	68.6	58.2	47.1	35.2	125.8	95.6	57.3	26.4
.72	135.8	109.6	83.2	71.4	58.5	44.6	135.5	109.3	72.7	36.2
.97	151.8	123.5	95.7	82.9	68.8	53.2	140.7	117.7	85.3	46.6
1.16	161.3	132.1	103.5	90.1	75.3	58.8	142.9	121.5	92.2	53.8
1.37	169.3	139.6	110.3	96.5	81.2	64.0	144.2	124.1	97.6	60.8
1.57	175.1	145.2	115.4	101.4	85.7	68.0	145.0	125.6	101.2	66.2
1.70	178.6	148.6	118.5	104.4	88.5	70.6	145.5	126.5	103.3	69.7
1.83	181.6	151.4	121.2	107.0	91.0	72.8	145.7	127.1	104.8	72.6
1.97	184.4	154.1	123.7	109.4	93.3	75.0	146.1	127.7	106.3	75.5
2.12	187.0	156.7	126.2	111.8	95.6	77.1	146.3	128.2	107.5	78.3

TABLE XXXVII.—KUTTER AND D'ARCY FORMULAS

## APPLIED TO CIRCULAR PIPES RUNNING FULL

Contrasting the pronounced and peculiar influence of  $s$ , upon  $c$ , in Kutter's formula, with the slight effect of D'Arcy's feeble and vanishing numerical increment.

Sine of angle of inclination is written above.  
Below in parenthesis the fall in feet per mile.

$\sqrt{r}$ feet	Kutter, when $n = .011$				D'Arcy
	.00005 (.264)	.0001 (.528)	.0003 (1.58)	.001 (5.28)	New Cast- iron Pipe.
.5	83.3	92.5	101.6	105.7	109.28
.6	94.0	102.9	111.5	115.2	110.59
.7	103.5	111.8	119.7	123.1	111.40
.8	111.9	119.6	126.8	129.8	111.94
1.0	126.4	132.6	138.2	140.4	112.58
1.2	138.4	143.0	146.9	148.6	112.93
1.5	152.8	155.1	156.9	157.7	113.22
1.8	164.3	164.3	164.4	164.4	113.38
2.1	173.5	171.7	170.2	169.6	113.48
2.5	183.5	179.3	176.1	174.9	113.56

$\sqrt{r}$ feet	Kutter, when $n = .017$				D'Arcy
	.00005 (.264)	.0001 (.528)	.0003 (1.58)	.001 (5.28)	Old Cast- iron Pipe.
.5	47.2	52.3	57.6	60.1	73.51
.6	54.2	59.2	64.4	66.8	74.39
.7	60.5	65.4	70.4	72.6	74.93
.8	66.8	71.1	75.6	77.7	75.29
1.0	76.7	80.7	84.4	86.0	75.72
1.2	85.7	88.7	91.5	92.6	75.96
1.5	96.9	98.5	99.8	100.4	76.16
1.8	106.2	106.3	106.3	106.3	76.26
2.1	114.0	112.7	111.5	111.0	76.33
2.5	122.7	119.6	117.0	116.0	76.38

TABLE XXXVIII.—KUTTER AND BAZIN FORMULAS

## APPLIED TO FLUMES AND OPEN CHANNELS

Contrasting the pronounced and peculiar effect of  $s$ , upon the value of  $c$ , in Kutter's formula, with the fact that in none of the Bazin formulas are the coefficients of flow materially affected by any change in slope.

Sine of angle of inclination is written above.

Below in parenthesis the fall in feet per mile.

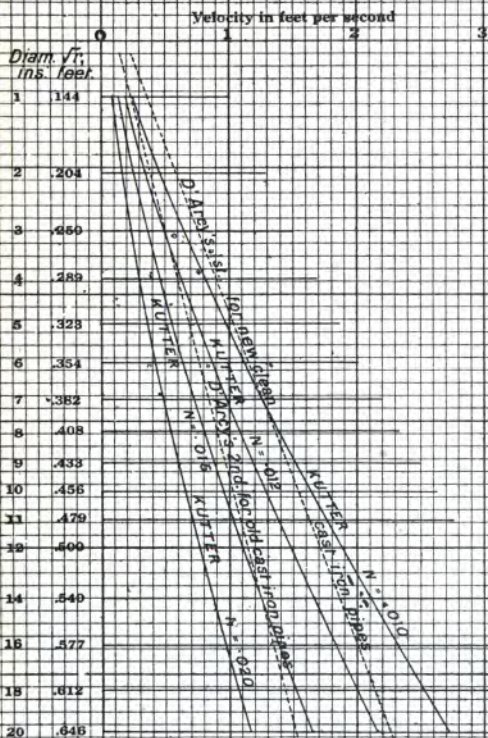
$\sqrt{r}$ feet	Kutter, when $n = .012$				Bazin	Kutter, when $n = .015$				Bazin
	.00005 (.264)	.0001 (.528)	.0003 (1.58)	.001 (5.28)	First Form.	.00005 (.264)	.0001 (.528)	.0003 (1.58)	.001 (5.28)	Second Form.
.5	74.3	82.5	90.8	94.6	125.27	55.5	61.6	67.9	70.8	94.87
.6	84.1	92.1	100.0	103.4	131.06	63.4	69.4	75.5	78.3	102.68
.7	92.9	100.5	107.7	110.9	134.95	70.4	76.2	82.0	84.6	108.43
.8	100.8	107.9	114.4	117.2	137.68	77.1	82.5	87.8	90.1	112.73
1.0	114.4	120.1	125.3	127.4	141.10	88.6	93.1	97.3	99.1	118.50
1.2	125.7	130.0	133.7	135.3	143.08	98.3	101.8	104.9	106.2	122.03
1.5	139.5	141.6	143.4	144.1	144.75	110.5	112.2	113.7	114.5	125.17
1.8	150.6	150.6	150.7	150.7	145.69	120.4	120.4	120.5	120.5	126.98
2.1	159.6	157.8	156.4	155.8	146.27	128.6	127.1	125.9	125.4	128.11
2.5	169.3	165.3	162.2	161.0	146.74	137.7	134.3	131.5	130.4	129.06

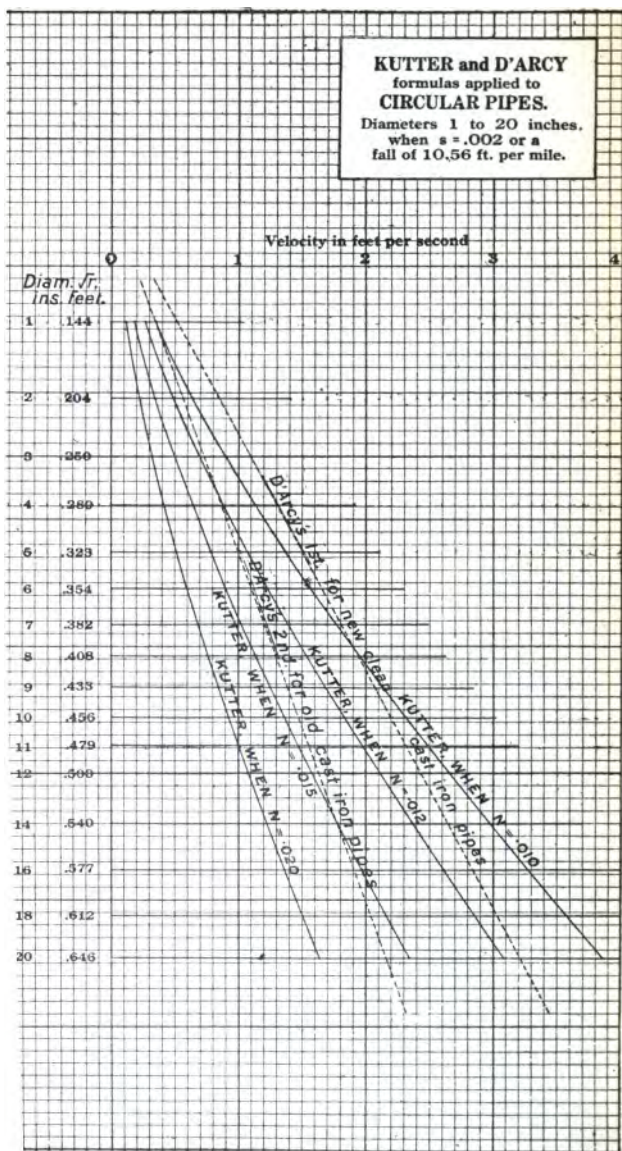
$\sqrt{r}$ feet	Kutter, when $n = .020$				Bazin	Kutter, when $n = .025$				Bazin
	.00005 (.264)	.0001 (.528)	.0003 (1.58)	.001 (5.28)	Third Form.	.00005 (.264)	.0001 (.528)	.0003 (1.58)	.001 (5.28)	Fourth Form.
.5	38.3	42.3	46.6	48.6	56.51	28.9	31.7	34.8	36.3	25.95
.6	44.2	48.2	52.4	54.4	64.58	33.5	36.4	39.5	41.0	30.75
.7	49.6	53.6	57.6	59.5	71.50	37.9	40.7	43.8	45.2	35.36
.8	54.7	58.4	62.2	64.0	77.41	42.0	44.7	47.6	48.9	39.77
1.0	63.7	66.9	70.1	71.5	86.66	49.4	51.8	54.3	55.4	47.93
1.2	71.6	74.1	76.5	77.6	93.33	56.0	58.0	59.9	60.7	55.18
1.5	81.7	83.1	84.2	84.8	100.09	64.7	65.8	66.7	67.2	64.43
1.8	90.2	90.3	90.4	90.4	104.45	72.2	72.2	72.3	72.3	71.91
2.1	97.5	96.3	95.3	94.8	107.37	78.7	77.7	76.8	76.4	77.92
2.5	105.7	102.9	100.5	99.6	109.93	86.1	83.8	81.7	80.9	84.12

**KUTTER and D'ARCY**  
formulas applied to  
**CIRCULAR PIPES.**

Diameters 1 to 20 inches  
when  $s = .001$  or a  
fall of 5.28 ft. per mile

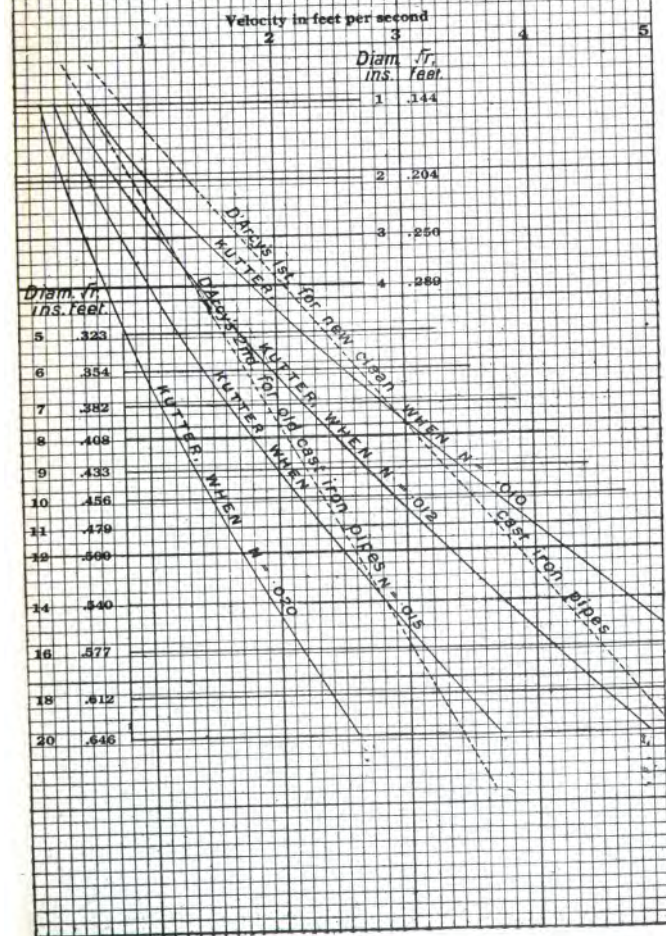


## CHART II



**KUTTER and D'ARCY**  
formulas applied to  
**CIRCULAR PIPES.**

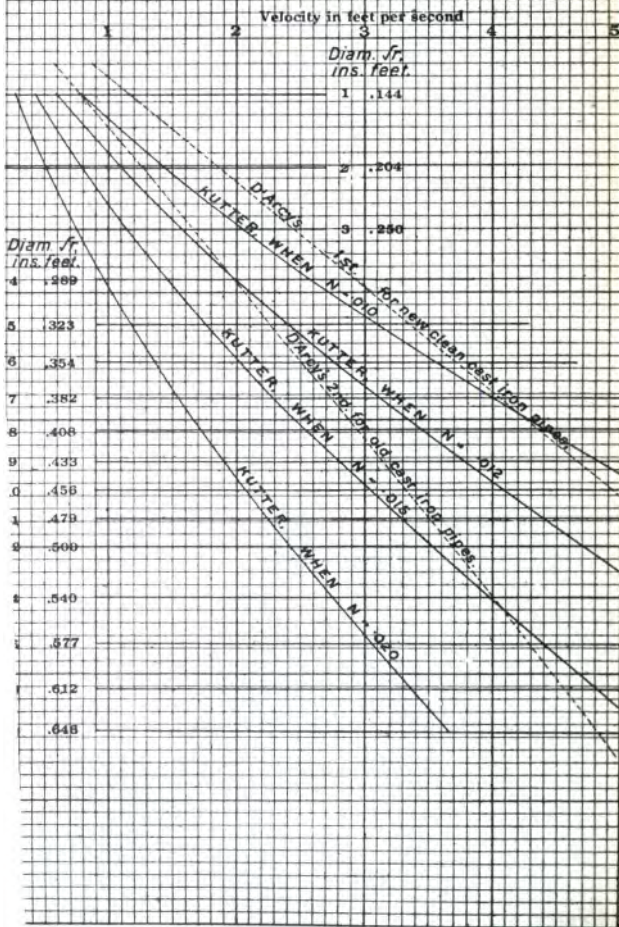
Diameters 1 to 20 inches,  
when  $s = .005$  or a  
fall of 26.4 ft. per mile.

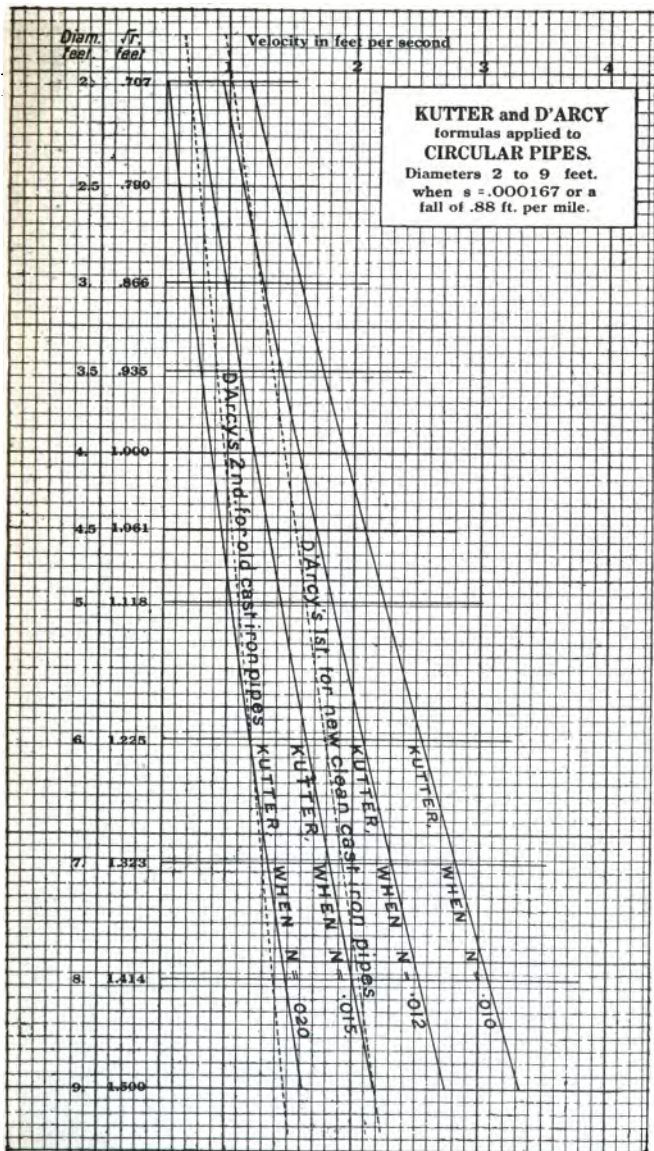


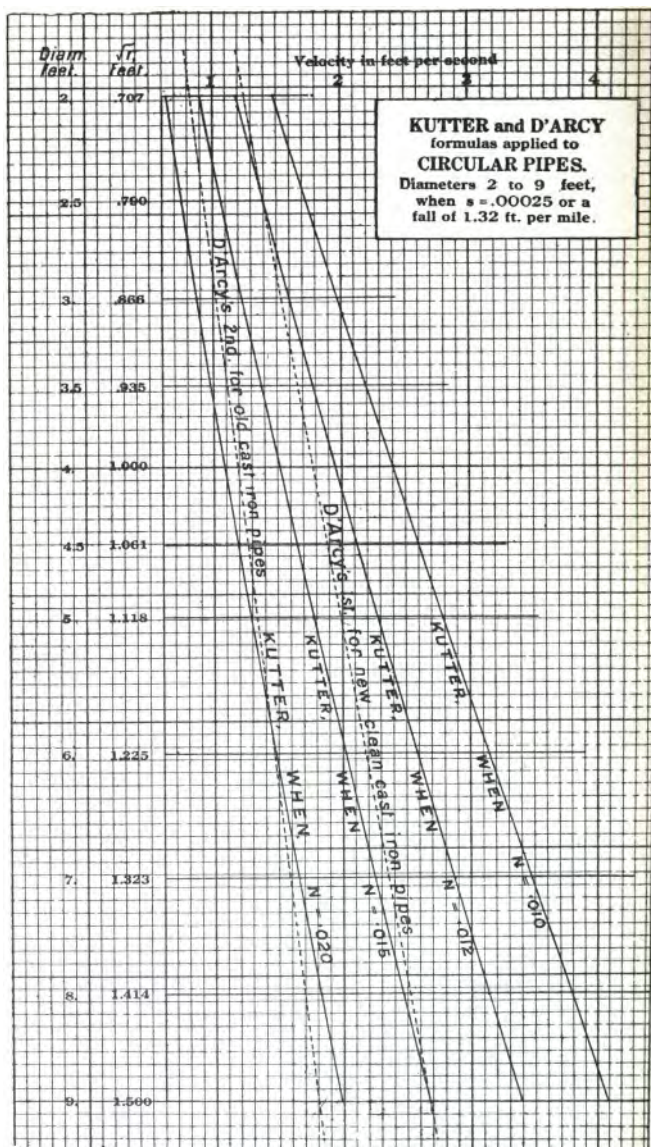
# CHART IV

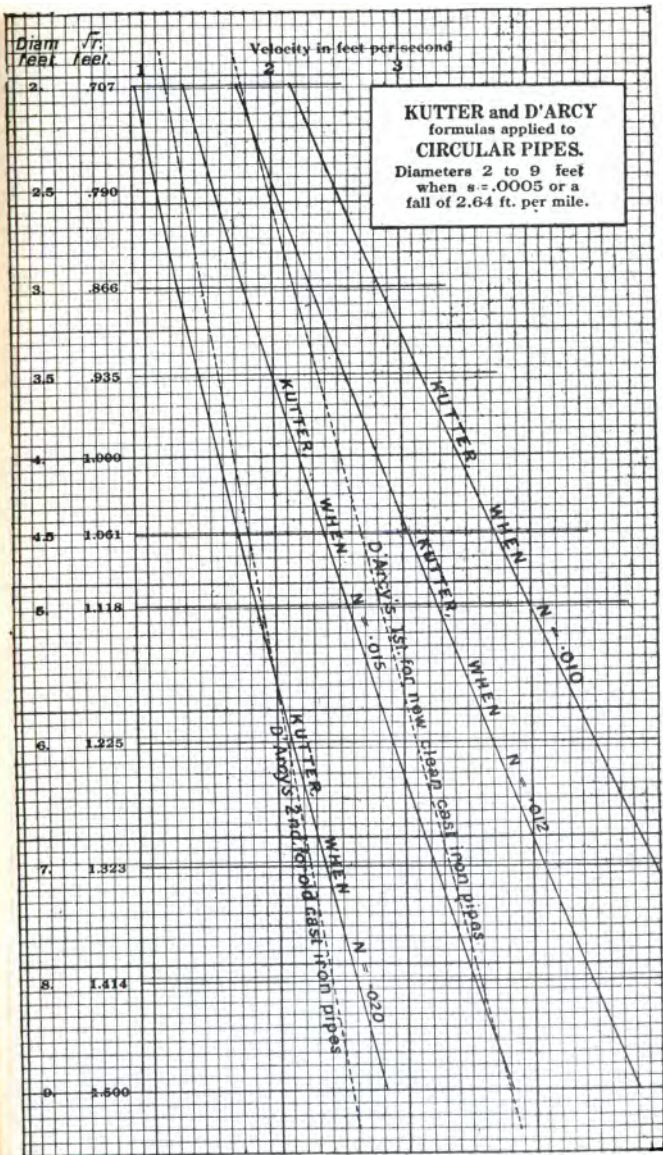
## KUTTER and D'ARCY formulas applied to CIRCULAR PIPES.

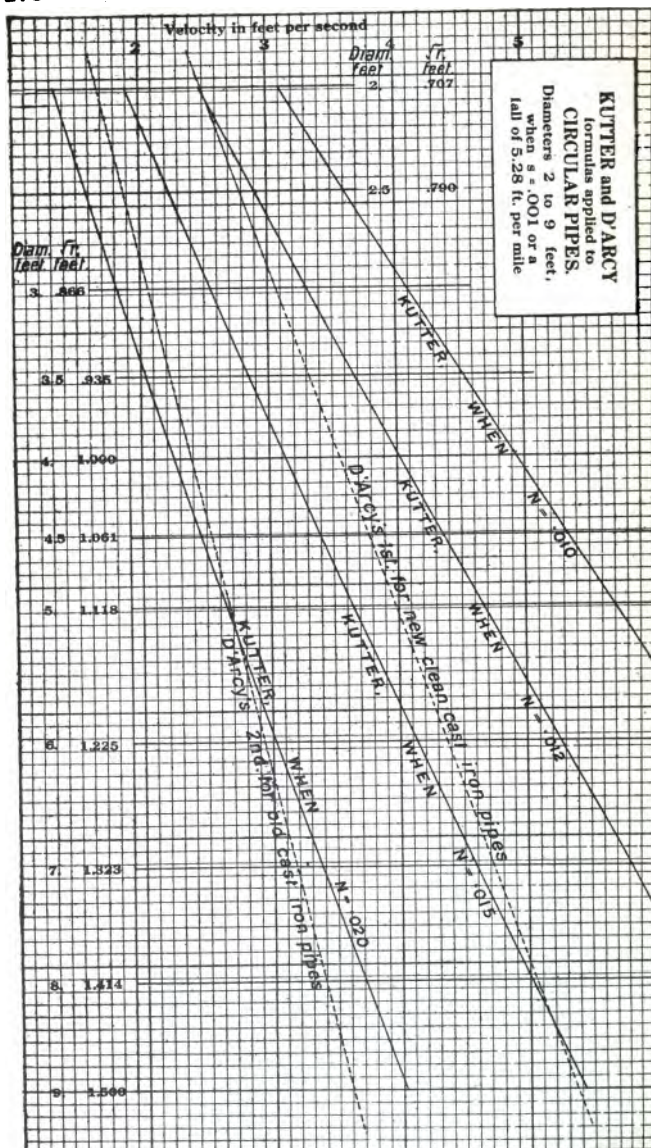
Diameters 1 to 20 inches,  
when  $s = .010$  or a  
fall of 52.8 ft. per mile







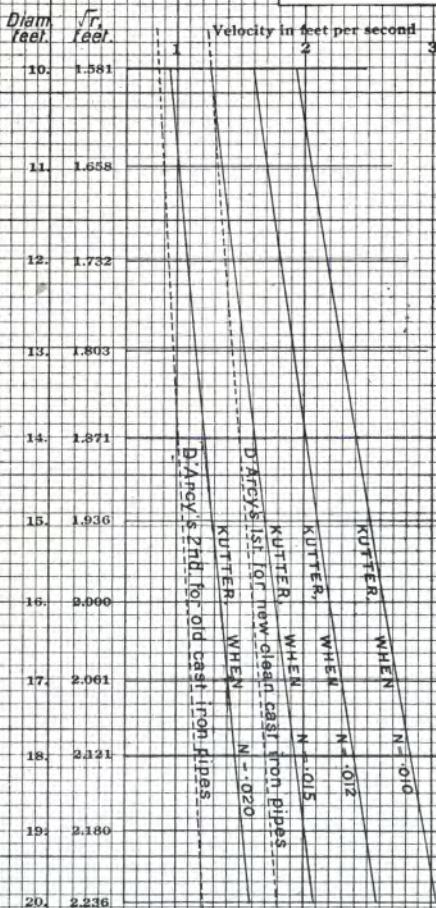




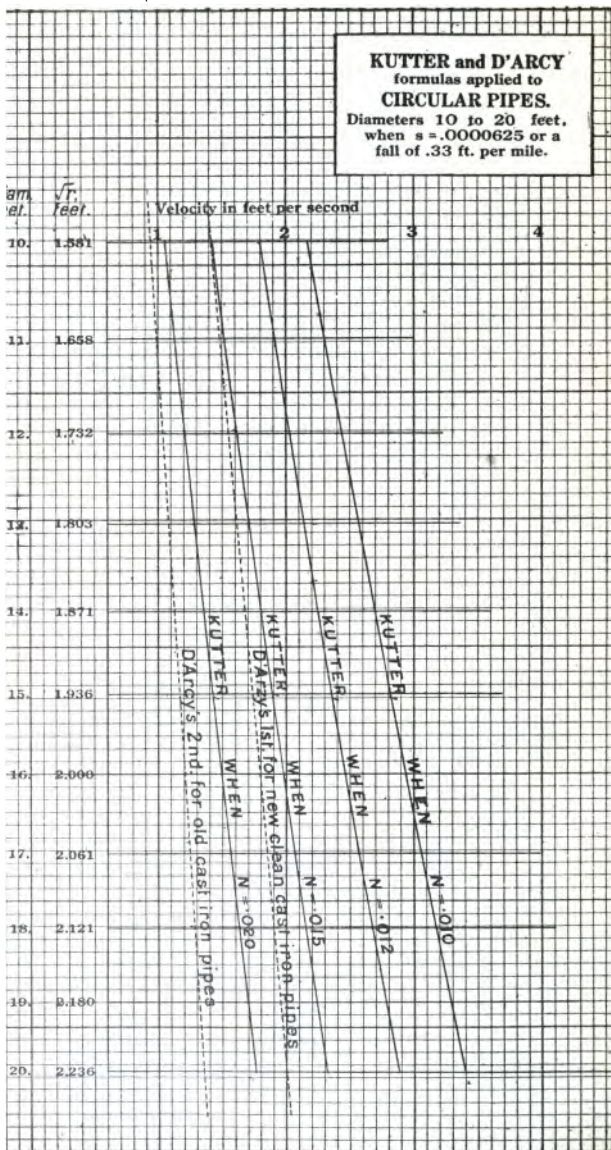
# CHART IX

## KUTTER and D'ARCY formulas applied to CIRCULAR PIPES.

Diameters 10 to 20 feet  
when  $s = .00005$  or a  
fall of .264 ft. per mile.



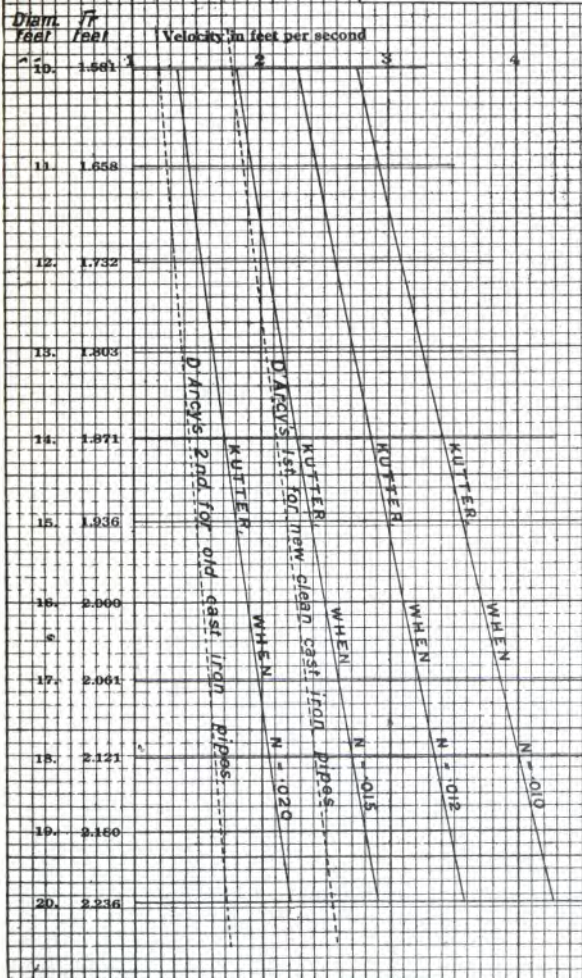
# CHART X



# CHART XI

## KUTTER and D'ARCY formulas applied to CIRCULAR PIPES.

Diameters 10 to 20 feet  
when  $s = .0001$  or a  
fall of .528 ft. per mile.



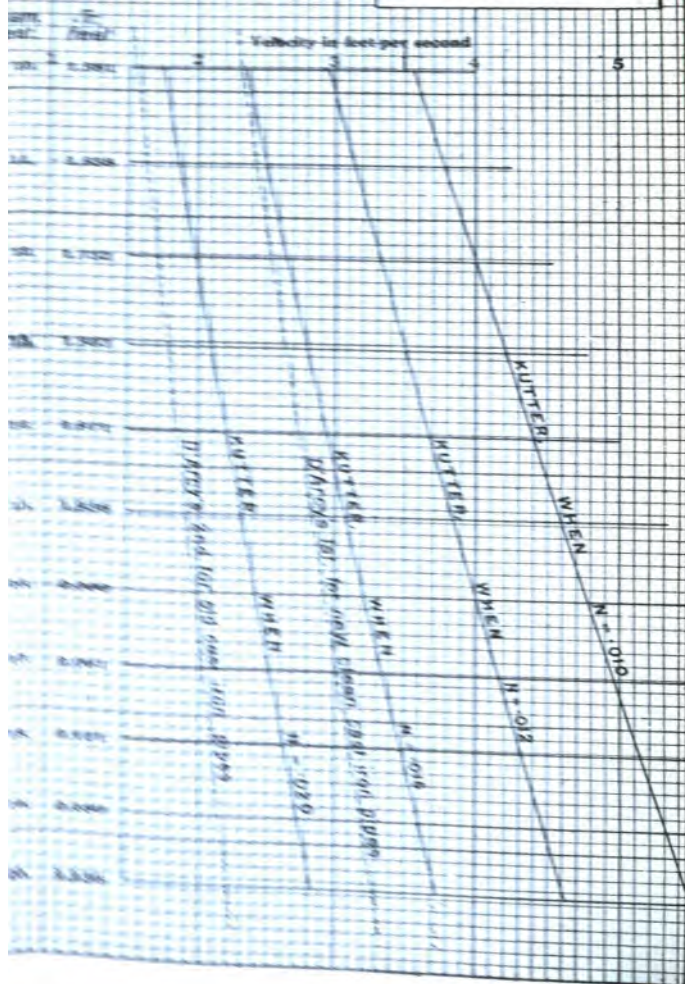
## CHART XII

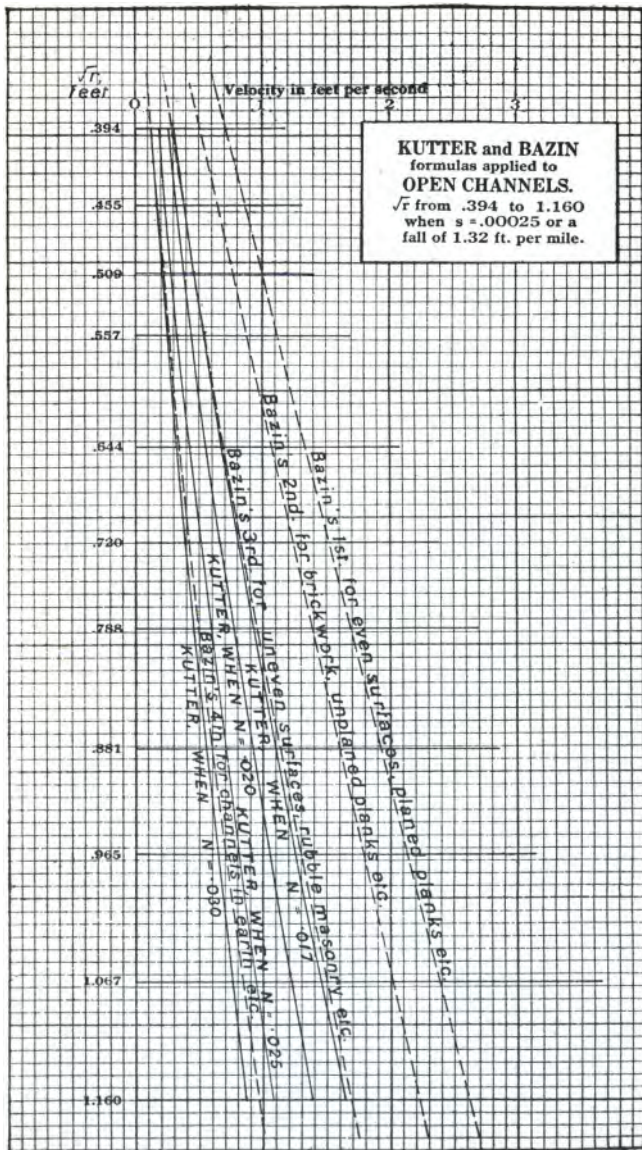
KUTTER and D'ARCY

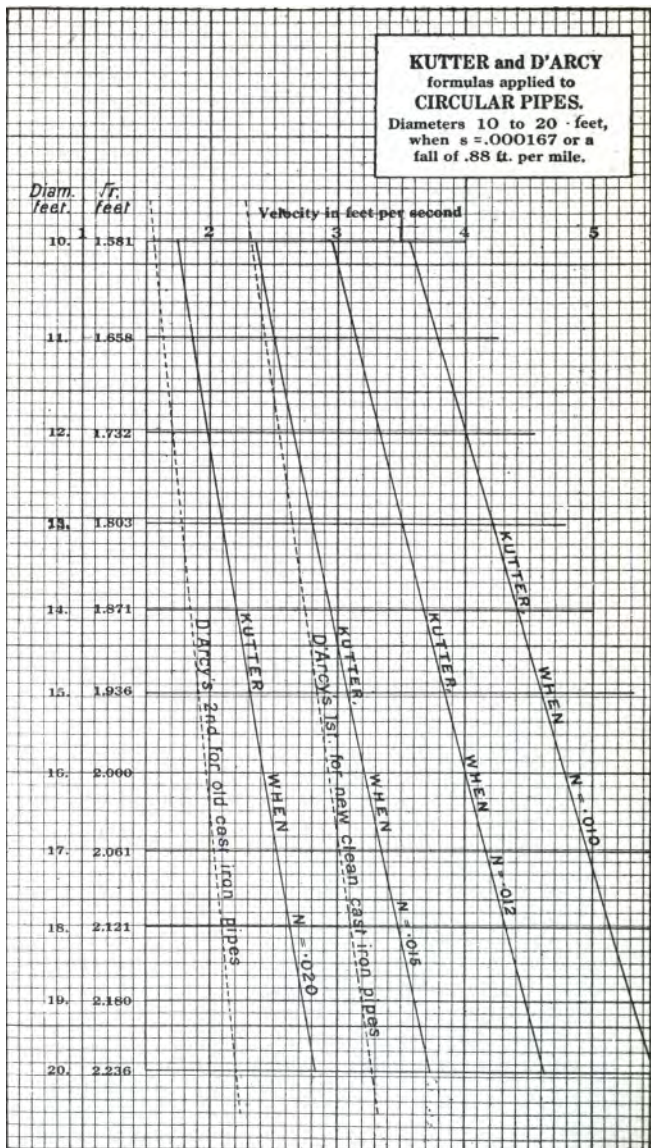
formulas applied to

### CIRCULAR PIPES.

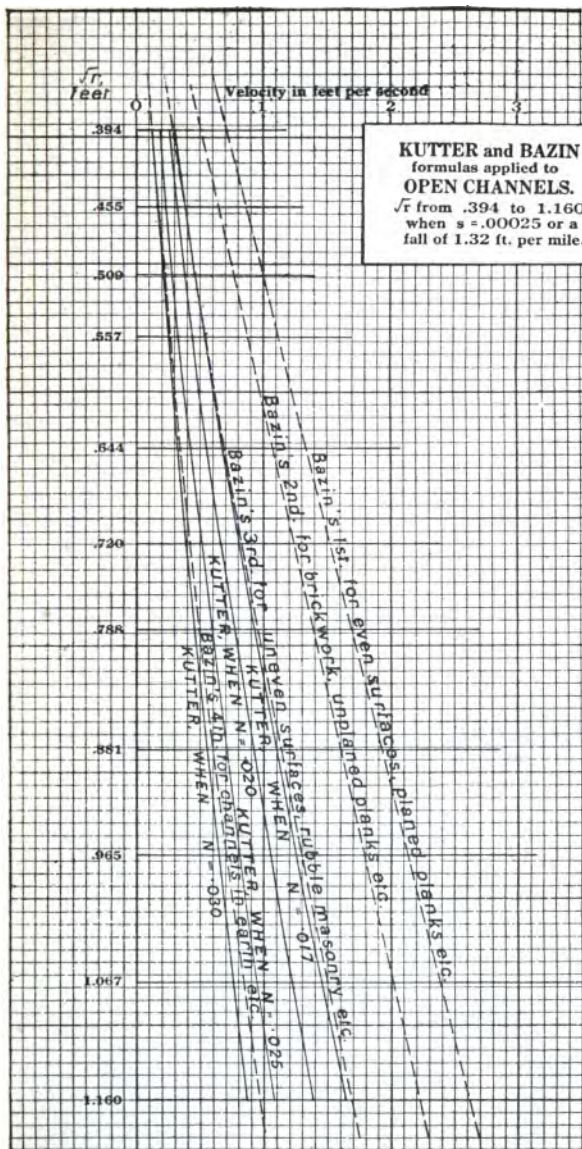
Diameters 10 to 20 feet,  
when  $s = .000167$  or a  
fall of .88 ft. per mile.

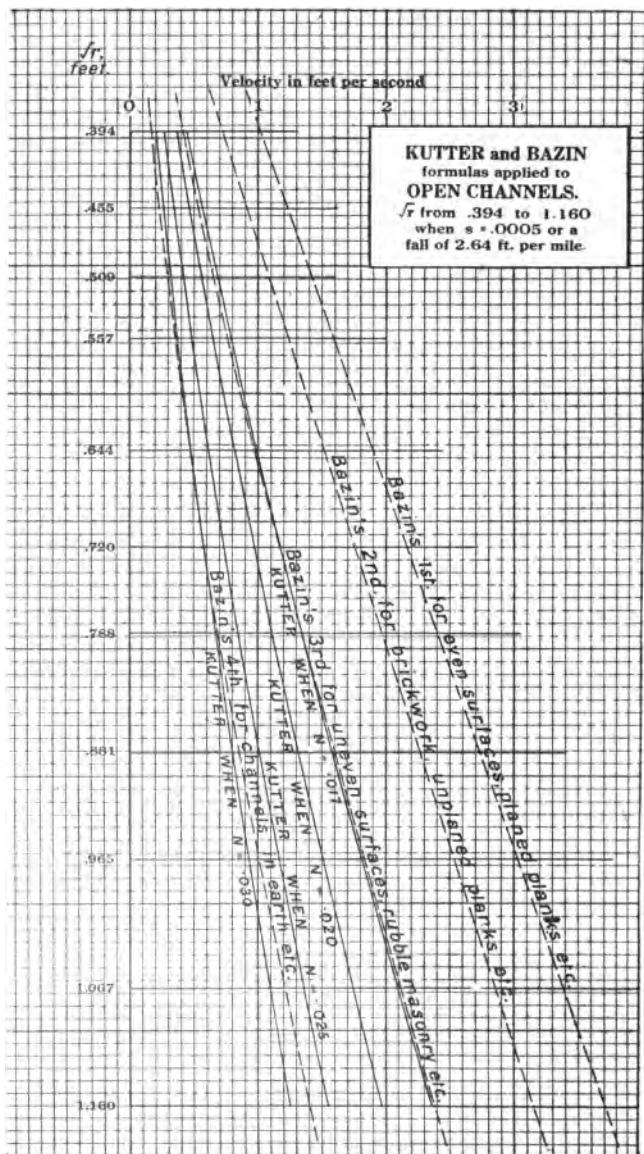




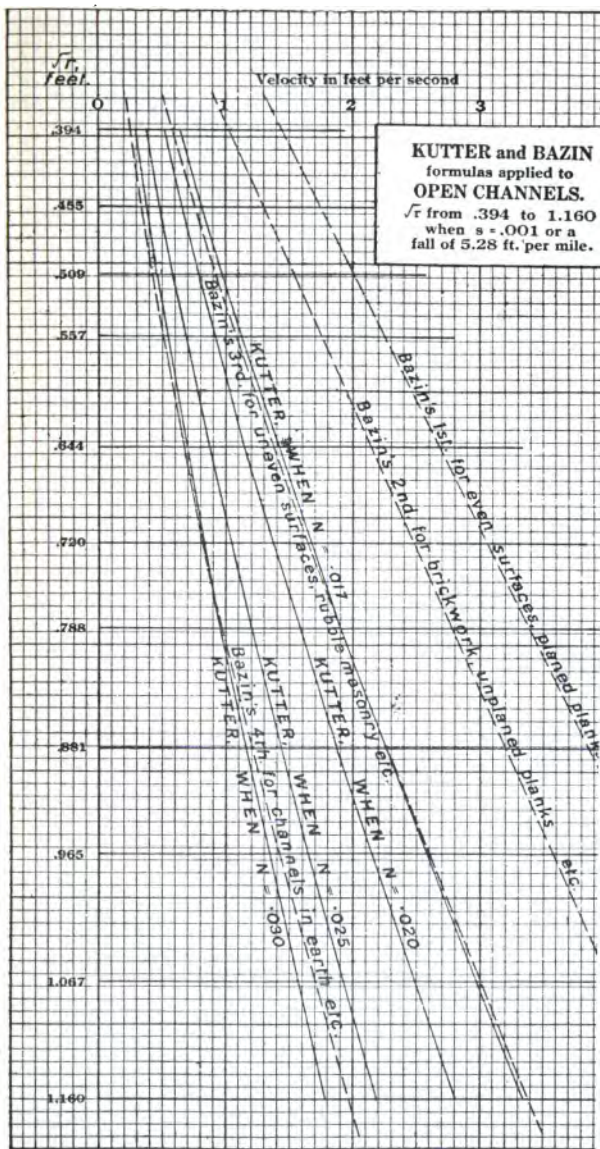


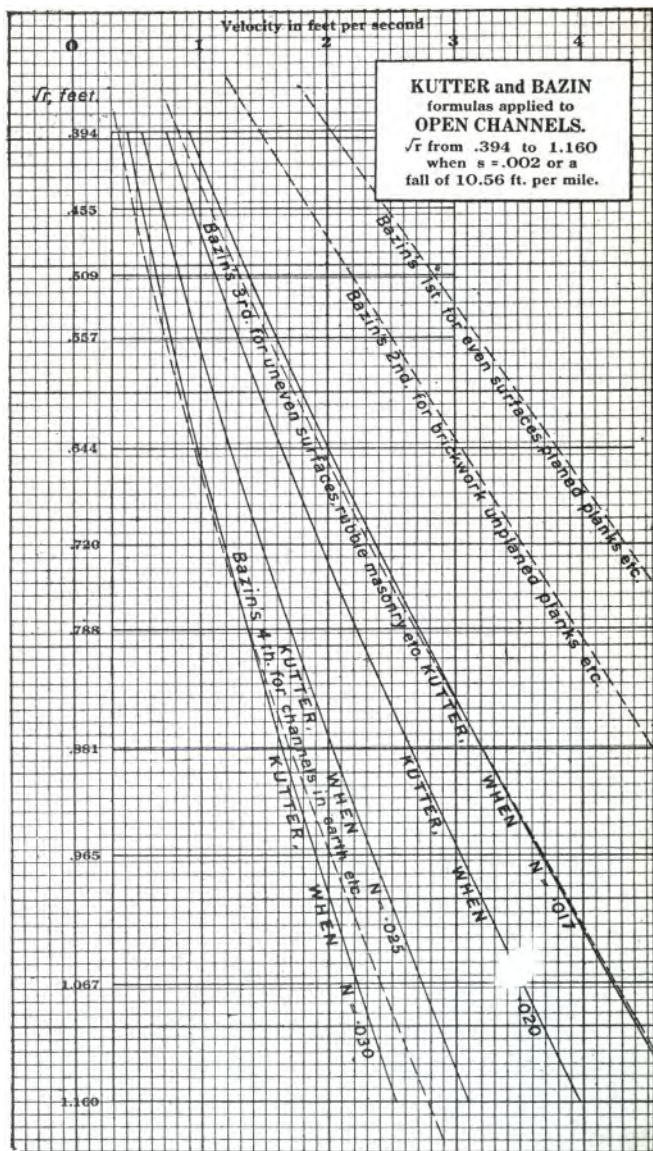
# CHART XIII

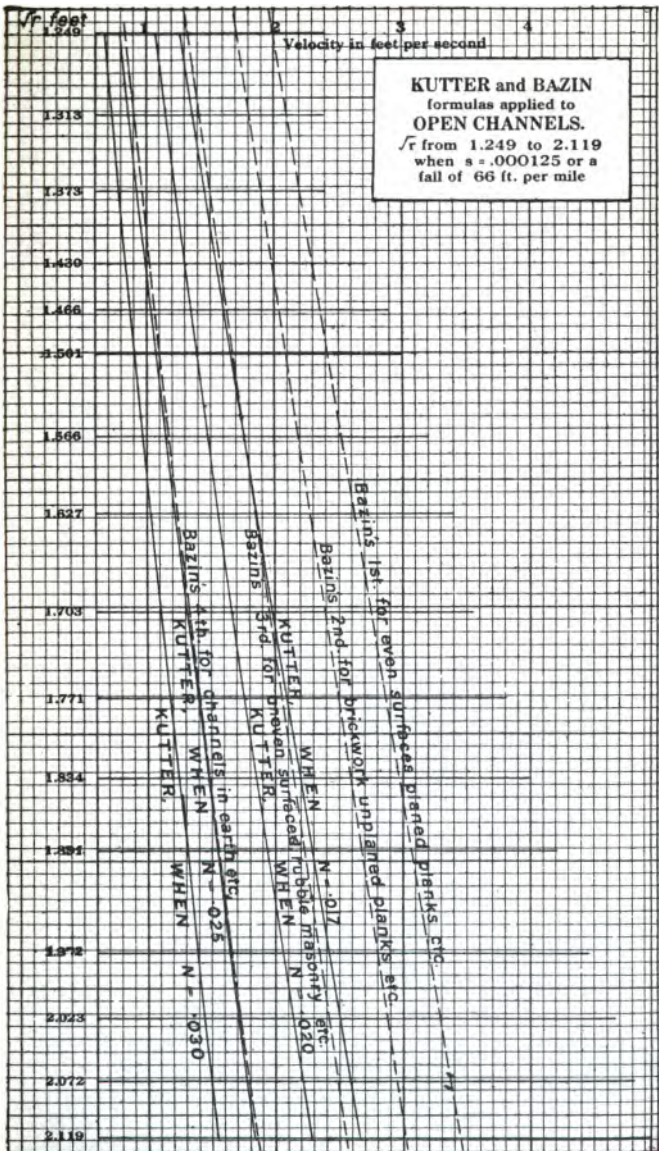


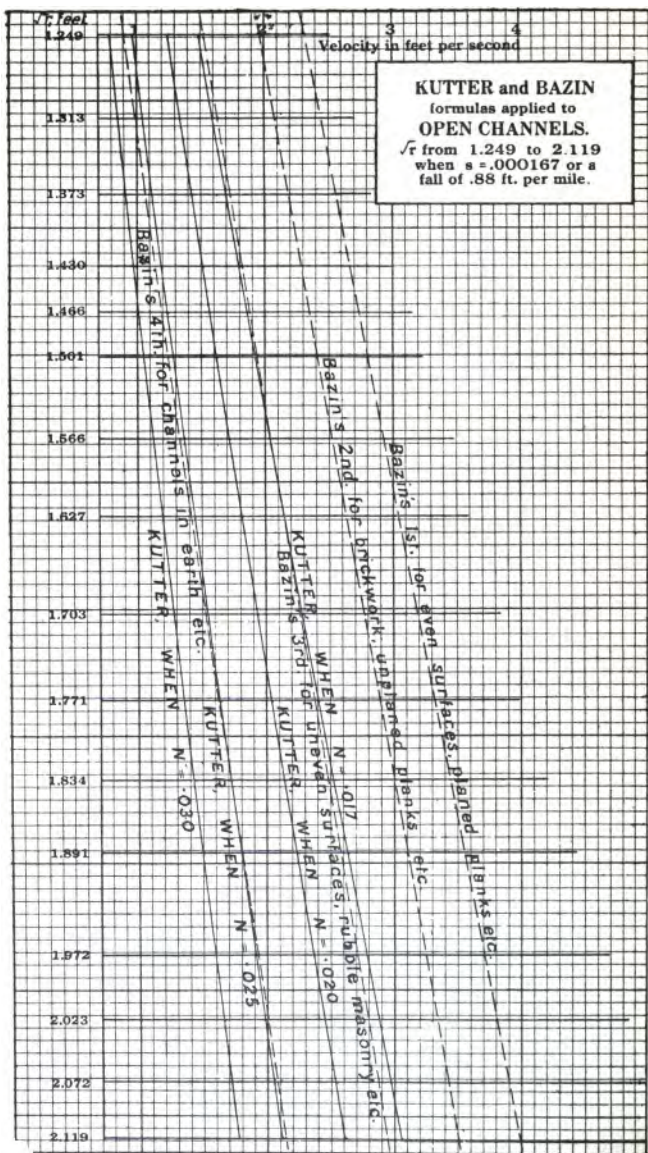


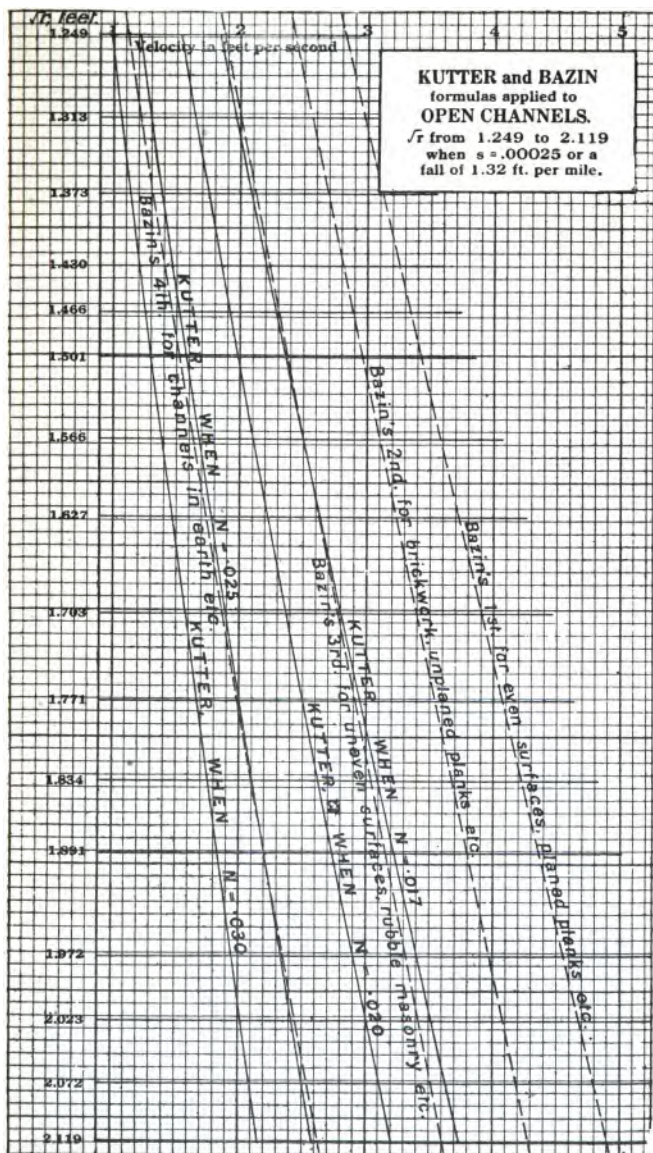
### CHART XV



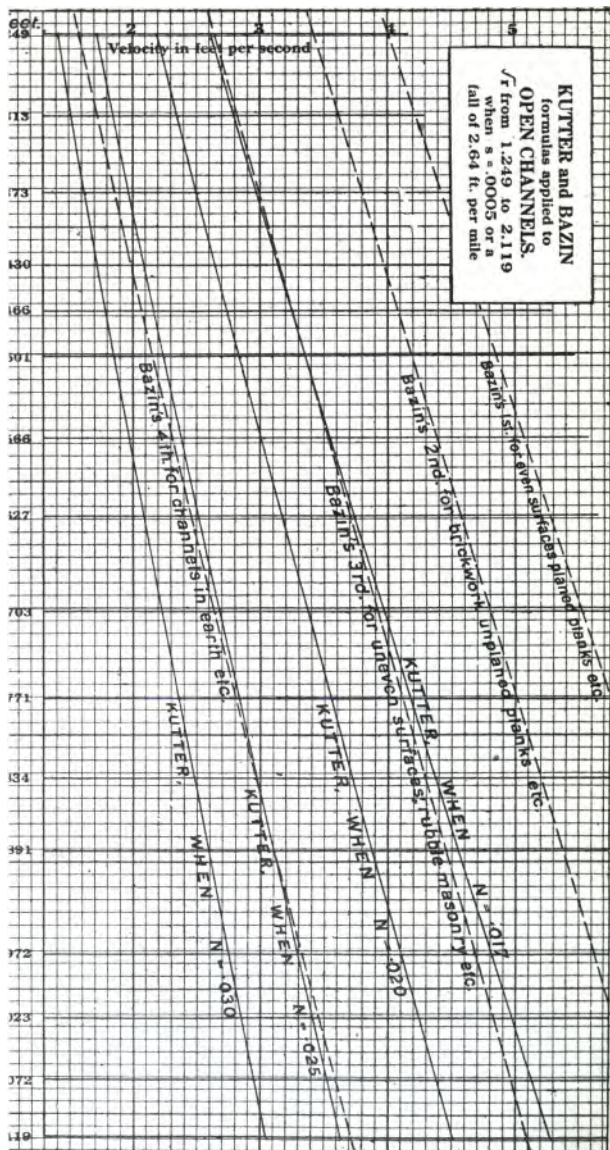


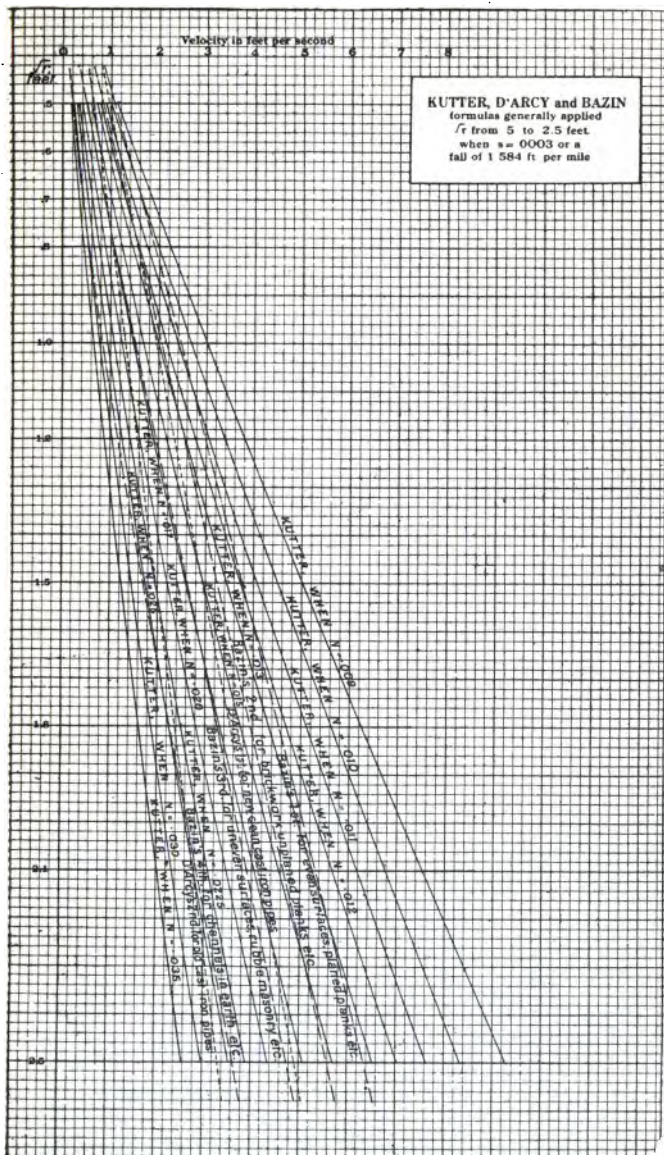


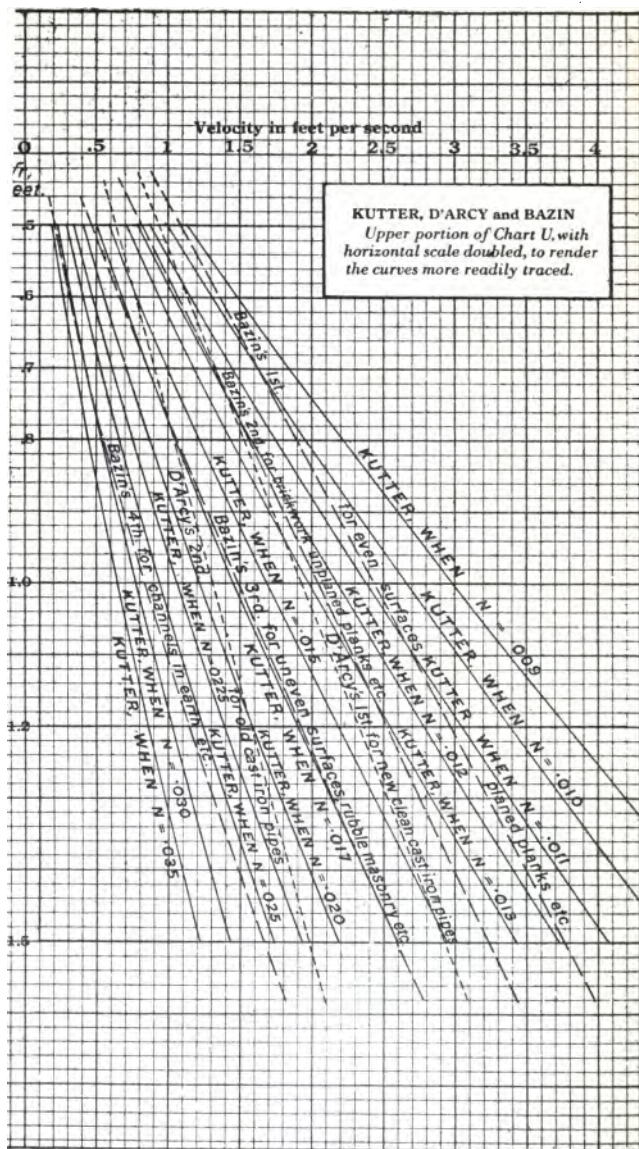




# CHART XX







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